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LAGOON PERFORMANCE AND THE STATE OF LAGOON TECHNOLOGY

George Barsom

Ryckman, Edgerley, Tomlinson and Associates, Incorporated
St. Louis, Missouri

June 1973

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State of Lagoon Technology

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Inventory and operative data from municipal lagoon facilities have been collected and evaluated. The adequacy of such facilities to produce effluent to meet state water quality criteria for receiving waters has been evaluated. (EPA)

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The phenomenal growth of oxidation lagoons as a form of municipal waste treatment is a reflection of their relatively low cost and ease of maintenance.

The widespread acceptance of lagooning was originally predicated on their ability to produce effluent quality at least equivalent to accepted secondary treatment. In the semi-arid Great Plains states where lagoons were originally successful, such efficiencies were easily achieved for most of the year. Unfortunately, differences in climate (especially sunlight and rainfall), soil type, population density and a multitude of diverse problems have worked against such success for other portions of the country.

Inventory and operative data from municipal lagoon facilities have been collected and evaluated. The adequacy of such facilities to produce effluent to meet state water quality criteria for receiving waters has been evaluated.

Factors limiting lagoon performance are discussed, including organic and hydraulic overload, odor and aesthetic failures, wind, light, mixing, data gathering and reporting and other problems. A series of recommendations for upgrading lagoon performance is included with critiques of the accuracy of current lagoon effluent reporting systems and the 1970 International Symposium on Lagoon Performance.

This report was submitted by Ryckman, Edgerley, Tomlinson and Associates, Inc., St. Louis, Missouri, in fulfillment of Contract Numbers 14-12-892 and 68-01-0014 under the sponsorship of the Environmental Protection Agency.

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SECTION I
CONCLUSIONS

PROBLEMS AND LIMITING FACTORS OF LAGOONS

This chapter discusses observed and reported operating problems of lagoons. These problems were uncovered in contacts with state engineers, reports from the literature, the Second International Symposium, and other professional meetings. Lagoon problems are broadly based in three areas;

1. effluent quality;

2. odors and other aesthetic failures; and

3. water loss.

Each of these areas will be discussed here along with a number of general problems. The conclusion reached is that design criteria tend to cause some of these problems and elimination of the problems may be brought about by changes in design; this will be discussed later in this section.

EFFLUENT QUALITY

Short-circuiting is one of the important problems in most lagoons in the U.S. and is probably much more common than realized. Wind factors can drastically affect short-circuiting and cause a relatively untreated effluent to be discharged. A number of cells in series would help reduce this problem. When short-circuiting occurs the detention time in the lagoon becomes less than the calculated design time and treatment efficiencies may suffer. Short-circuiting in a lagoon is often encouraged and enhanced by the design itself. Ten State Standards requires the inlet pipe to the first cell of a lagoon system to be in the bottom, between 1/3 and 1/2 way along the length of the lagoon. Thus before anything else is said the design encourages a portion of the lagoon to be less heavily used and encourages the flow to tend toward the effluent pipe without circulating through the lagoon.

This phenomenon is, in fact, true. Studies at lagoon systems in California measured detention times as low as one percent of the calculated time. For example, at Shastina, in a four cell lagoon system, dye was observed in the effluent 2/3 of a day after it was introduced to the plant influent. The design detention time for this system was 80 days. Other measurements on this same lagoon gave a mean detention time of 11 days. It is not possible to achieve a consistently high quality effluent with such variation in detention time. Bacteria counts for fecal coliform (MPN/100 ml) ranged from 24 million to less than 45 during these flow tests and cannot meet California's standards for a chlorinated effluent. Permits are granted for these lagoon systems based on the theoretical detention time that coliform die-off could be adequate.

Illinois allows a 75 percent reduction of BOD per cell of a lagoon based on 7 days detention time. The California studies show that this time is not likely to be realized if conventional designs are used. Analysis of design criteria, which is frequently the Ten State Standards or a minor modification shows one glaring feature which tries to insure easy operation by preventing scum or floating solids accumulating. That feature is contained in Section 92.5 "Pond Shape". "No islands, peninsulas, or coves should be permitted". Islands, peninsulas and coves when spaced through the lagoon can serve as very effective baffles to break up the flow of liquid and prevent short-circuiting. Adding baffles to a lagoon should be a fairly simple way to insure that actual detention time will approximate the design detention.

Unfortunately, almost no data, other than the previously cited California studies, has been found which shows the actual detention time, or even the degree of treatment a waste stream is receiving.

To quote the California study again: "Lagoons with a discharge cannot be depended on to provide disinfection unless or until short-circuiting can be reduced so actual holding time approaches calculated detention; this will provide greater sewage organism reduction and reduce the probability of particulate matter or relatively untreated sewage flowing through the lagoon system in a few hours".

Lagoon systems should be designed with a minimum of three and preferably more series operated lagoons to reduce short-circuiting. Baffled inlets or other flow despersion methods should be included in lagoon design.

These methods should be developed to provide more accurate lagoon flow or detention measurement. Further tests with better tracer dyes and/or other methods are needed to develop accurate lagoon flow test methods.

With development of accurate lagoon flow test methods more sewage organism testing is necessary to correlate bacteriological organism reduction with lagoon detention or holding time, and other factors.

Thus, short-circuiting is a frequently overlooked problem area in lagoon performance. The upgrading of lagoon effluent quality can be expected to benefit greatly by the effective baffling of the lagoons.

Thermal Stratification - Observing stratified lagoons, Drews (55) determined the extent to which short-circuiting occurred at six South African lagoons. Table 1 summarizes the time required for fluorescein dye, injected in the influent, to reach the effluent structure in concentrations great enough to be detected visually. It may be noted times required for short circuiting ranged from 17 minutes to about 6 hours. Comparing this range with the normal detention time of 30 days, it becomes clear why a stratified lagoon and favorable wind conditions can cause short-circuiting and result in reduced lagoon effluent quality.

Hydraulic Overload - When a lagoon is hydraulically overloaded the high rate of discharge may create turbulent flow conditions around the discharge pipe structure.

This high flow rate carries the suspended algae out the overflow pipe and leads to further degradation of the receiving stream.

In a conventional treatment plant, great efforts are expended to provide weir structures which will control the rate of flow as the effluent approaches the collection and discharge point. This idea seems to have been lost in designing lagoons.

Hydraulic overload may go hand in hand with organic overloading. More frequently, the addition of storm water drainage or the intrusion of water from subsurface soil may be at fault. If percolation and evaporation rates have been miscalculated these factors could also contribute to the problem.

The most frequent cause of overloading results from facilities which have the design capacity exceeded. This frequently happens in more remote areas where the facility is apparently functioning well and new service is extended and added to the existing plant without upgrading. Undoubtedly, some of this can be tolerated but soon reaches a point where the design capacity is so overloaded that poor quality effluent is swept from the facility.

While this may be a problem for small municipalities it reaches its greatest magnitude in near urban areas for facilities not classified as municipal, i.e., trailer courts and the like. Some of the worst examples found anywhere in the country occur in Jefferson County, Missouri where population expansion has occurred at a rapid and rather uncontrolled rate. A temporary permit issued ten years ago for 20 unit facility may now have as many as 200 units on line. The temporary permit was never finalized, a new permit was never sought and a water control board, understaffed and relatively inexperienced, having no legal authority to implement their recommendations, is found to be relatively powerless to do anything about the situation. Of course, the plant fails to achieve the desired degree of treatment. Does this mean that lagoons are not an adequate form of treatment? No treatment facility could produce a satisfactory product under these circumstances. It should be pointed out that while each of these situations is admittedly small the aggregate of them produces a monstrous quantity of poorly treated wastewater entering small, once clear, receiving streams. No valid estimates of the total of such facilities could be obtained for this study.

TABLE 1

Lagoon Short-Circuiting South African Dye Studies [117]

Lagoon	Time for Dye to Reach Effluent
Parys	Prim. Pond: 17 min. W/wind, <60 min. against wind
Standerton	Prim. Ponds: <25 min. Sec. Pond: 1.5 hours
Louis Trichards	Prim. Pond: 6 hours Sec. Pond: 5 hours
Dundee	Prim. Pond: <1 hour Sec. Pond: 4 hours
Stellenbosch	Prim. Pond: 1.5 hours Sec. Pond: 2 hours
Uitenhage	n.a.*

*n.a. not available

Where land for expansion exists, additional cells could be constructed to accommodate the added volume. In too many instances low cost housing has been permitted up to the limits of the existing facility and insufficient land was set aside originally to accommodate added facilities. Added cells, while useful to contain added volume serve another valuable function. As previously stated, they increase the retention time, reduce short-circuiting, reduce coliform counts and generally produce a successively better effluent. They do not, however, meet some of the major objections to lagoon treatment performance. What we see is a trade between one kind of waste (raw sewage) as a primary influent and an admittedly esthetically more satisfying form of organic matter (algal cells) as an ultimate effluent. While this effluent is biologically "cleaner" it does, nevertheless, contribute to stream water quality degradation.

Light - The significant role of sunlight in oxidation pond failures is evident from the following discussion which tabulates the types of failures attributable to diurnal and seasonal fluctuations in available sunlight. During times of high light intensity, algae grow well and photosynthetic oxygen evolution meets or exceeds the BOD. However, due in part to daily and seasonal fluctuations of light intensity, effluent and aesthetic oxidation pond failures occur.

Photosynthetic oxygenation is a function of light intensity. Because of reduced or fluctuating light intensities, evolution of photosynthetic oxygen may be insufficient to satisfy the BOD, resulting in anaerobic conditions. Extended anaerobic conditions have been shown to result in:

1. Evolution of hydrogen sulfide

2. Increased effluent BOD due to anaerobic end products in the reduced from, such as organic acids, aldehydes, alcohols and methane

3. "Pig-pen" odors due to decay of algae

4. Reduced algae synthesis with a concomitant reduction in inorganic removals

Optimum light intensities, conducive to algae growth, result in the following oxidation pond failures:

1. The growth of algae reduced light penetration and results in the failures listed above.

2. Optimum algae growth in lagoons results in a surface mat which inhibits light penetration. Eventually the algae mat decays, resulting in "pig-pen" odors and a deteriorated effluent quality.

3. Optimum algae growth has been shown to result in a dispersed microbial population which remains suspended in the lagoon effluent.

The magnitude and quantity of sunlight striking a given location depends upon season, geographic location with respect to latitude, time of day, the angular height of the sun, the elevation of the point of observation and the transmission quality of the atmosphere. Discussion of these various factors can be found in excellent review articles and will not be reported here. It is sufficient for our purposes to point out here that differences in light quality and quantity are partially responsible for some of the failures observed in coastal regions of the country.

Winds and Mixing - In the preceding discussion, winds have been implicated with short-circuiting. However, as shown by Barsom (36), they are also the prime driving force of vertical mixing and improved contact between substrate, organisms and photosynthetically-evolved oxygen. That the variable winds cannot be depended upon to thoroughly mix a lagoon's contents; resulting in thermal stratification, short-circuiting and reduced contact between substrate, organism and available molecular oxygen; can be ascertained by evaluating the detailed lagoon temperature profiles presented by Clare et al. (56), and discussed by Barsom (36). The thermal history for domestic lagoons may be summarized as follows. In the spring, there will normally be a period of circulation, the water is of the same temperature and density, and vertical circulation requires only minimal forces sufficient to overcome viscosity. Continued heating of the lagoon surface waters, as a result of absorbed solar radiation, interacts with wind-driven turbulence yielding a thermally stratified lagoon. In autumn, cooling at the surface causes a thickening of the epilimnion by convective mixing as the lagoon water temperature falls. In the fall, as in the spring, this process is normally followed by a period of circulation, and the water is of the same temperature and density throughout.

Winter Lagoon Failures Under Ice-Cover: During the winter the water immediately below the ice is substantially at 0°C, and lagoon bottom waters are not far from the maximum density (3.9°C). This is a comparatively stable equilibrium because the ice-cover prevents wind-induced turbulence and serves as thermal insulation.

At these low water temperatures under ice-cover, the prime treatment mechanism is sedimentation. Bacterial degradation is greatly reduced at these water temperatures. Algae activity is greatly reduced because of low water temperatures and reduced sunlight, due to seasonal variations and the presence of an ice-cover. Anaerobic conditions obtain because atmospheric reaeration and photosynthetic oxygenation are essentially nil, due to the ice-cover. Once anaerobic conditions obtain, the lagoon experiences the following failures:

1. Increased effluent BOD due to anaerobic end products as organic acids, aldehydes, alcohols and methane.

2. Increased effluent BOD. In these cold waters, sedimentation is the prime treatment method, bacterial activity is greatly reduced. Dissolved organic compounds are not removed effectively by sedimentation. These dissolved and colloidal organic compounds increase effluent BOD values.

3. Due to the greatly reduced microbial activity odor failures do not occur under ice-cover.

Spring Turnover Failures: When the lagoon ice-cover breaks up during the spring, the water near the surface begins to warm, establishing convection currents. When the water temperature is practically uniform at all depths, circulation becomes especially pronounced. During this period, the solids which settled under the ideal settling conditions of ice-cover are resuspended. This increased organic load, due to the resuspension of settled organic solids, greatly exceeds the dissolved oxygen resources of the lagoon waters. This results because atmospheric reaeration is not adequate to satisfy the oxygen demand; and the active algae population needed for photosynthetic oxygenation has not yet established itself so soon after the ice-cover breakup. Once anaerobic conditions are obtained, the lagoon is susceptible to the following failures:

1. Increased effluent BOD due to anaerobic end products as organic acids, aldehydes, alcohols and methane.

2. Increased effluent suspended solids due to the resuspension of organic solids which settled under the ice-cover.

3. Evolution of septic sewage odors.

Summer Stagnation Failures: Spring turnover is followed by summer stagnation. Summer stagnation is characterized by three layers: the epilimnion, metalimnion, and hypolimnion. The epilimnion consists of relatively freely-circulating water with a small and variable temperature gradient. Underlying the epilimnion is a metalimnic water layer, the entire volume of which is characterized by a rapid decrease in temperature with depth. Underlying the metalimnion is a relatively undisturbed cold water layer, or hypolimnion, in which the thermal gradient is roughly exponential. Such a stratified environment is often known as summer stagnation. Oxidation pond failures resulting from summer stagnation are:

1. Thermal stratification induces short-circuiting of influent raw wastewater, resulting in an inadequately stabilized lagoon effluent as evidenced by increased effluent BOD and suspended solids.

2. Abundant sunlight and warm water temperatures, associated with summer stagnation, are conducive to algae blooms. These algae greatly increase effluent BOD, suspended solids, nitrogen and phosphorus.

3. Algae-laden lagoon effluents adversely affect receiving water quality. Some of the failures associated with these polluted water algae are taste and odor, color, increased turbidity and clogging of the filters in a water treatment plant and the release of toxins.

4. Blooms and mats result in "pig-pen" odors emanating from the lagoon and cause severe taste and odor problems in receiving waters.

5. Summer stagnation isolates hypolimnic waters much as an ice-cover does in the winter. Anaerobic conditions obtain in the hypolimnion resulting in increased effluent BOD due to anaerobic end products as organic acids, aldehydes, alcohols and methane. Septic sewage and sulfide odors may obtain.

6. Thermal stratification greatly inhibits mixing between epilimnic and hypolimnic waters. Reduced contact between substrate and microorganisms increases the time required to accomplish stabilization. Insufficient stabilization results in deterioration of lagoon effluent quality.

Marais (57) has reported on the degree of mixing in stratified lagoons located in Lusaka, situated inland on the African plateau about 4,500 feet above sea level at about latitude 15° south. The maximum summer lagoon water temperature is about 32°C to 38°C, and the average minimum in winter is 10°C. These temperatures are not unlike those expected in temperate climates.

It is possible that during the summer, when the wind speeds are low, cooling by radiation and subsequent convection currents will not be sufficient to equalize the temperature throughout the pond, and a thermocline will persist. At Lusaka, the thermocline persisted for almost two months during 1963.

Fall Turnover Failures: When autumn comes, surface layers cool and sink, establishing convective currents which mix the water mass to greater and greater depths. When the temperature gradient becomes substantially vertical, the fall overturn takes place and the waters are put into circulation by autumn winds.

During the fall overturn, as during the spring overturn, organic bottom deposits are resuspended. During this period, the following failures may be experienced.

1. Increased effluent suspended solids results from the increased mixing associated with the fall overturn. Increased turbulence maintains solids suspension prior to effluent discharge.

2. Resuspension of organic bottom deposits reduces light penetration. Reduced light penetration will adversely effect photosynthetic oxygenation. Anaerobic conditions will obtain when the resuspended organic bottom deposits exceed the oxygen resources of the lagoon. The anaerobic environment will result in septic and sulfide odor generation and increased effluent BOD due to high-energy anaerobic end products as organic acids, aldehydes, alcohols and methane.

Solids Separation - Although lagoons serve partially as settling basins, an appreciable amount of solid material may leave the lagoon in the effluent. Figure 3 shows that for oxidation ditches, facultative aerated and tertiary lagoons, the average median effluent suspended solids ranged from 38 mg/l to 68 mg/l. Suspended solids of this magnitude do not meet standards for secondary treatment.

To improve this condition, a collection system of weirs such as would be used in a conventional treatment plant could be employed. This type of system could reduce the solids in the effluent, but would result in solids being deposited in the lagoon.

Organic Overload - The purpose of a lagoon is to provide adequate low-cost treatment of sewage without degrading the quality of the receiving streams. Lagoons do not seem to be able to consistently meet this goal for several reasons. At times, organic removal is low due to overloading, short-circuiting, low temperature, shock loads, or a combination of these. Lagoons are able to withstand shock fairly well, due to the large area and volume in which the waste is contained. However, prolonged organic loading at a rate greater than the capacity of the installation to provide purification will lead to a deteriorated quality effluent. Lagoons in the United States are frequently loaded at 200 people/acre/day or 34 lb.BOD/acre/day, assuming a population equivalent of 0.17 lb.BOD/person/day. Gloyna (39) points out that lagoons are capable of handling a higher loading than this, and that this loading has been found by trial and error to keep most lagoons odor free even at spring turnover conditions. In other parts of the world, loadings as high as 145 lb.BOD/acre/day are commonly used without sacrificing treatment efficiency.

ODORS AND OTHER AESTHETIC FAILURES

The chemical compound most often associated with odors from lagoons is hydrogen sulfide. The microorganisms able to produce sulfide are *Desulfovibrio desulfuricans* and *Clostridium nigrificans*.

The presence or absence of sulfide production in lagoons is dependent on certain operational and environmental parameters, such as:

1. Organic loading rate, lb BOD/acre/day.
2. Sulfate concentration in the carriage water.
3. Sulfate loading rate, lb $SO_4^=$/acre/day.
4. Presence or absence of dissolved oxygen.
5. Available light to drive photosynthetic oxygenation.
6. Water temperature.
7. Oxidation-reduction potential (ORP).
8. pH.

As might be anticipated in naturally complex biological systems similar to a lagoon, all of the parameters are complexly interrelated in a manner not fully defined. Various phases of this complex interaction, however, have been documented by several investigators. These reports will be evaluated to provide a clearer understanding of sulfide generation as a limiting factor in lagoon failures.

In laboratory investigations of facultative lagoons, Espino de la O and Gloyna (58) reported a correlation between the concentration of sulfate ion in the influent and the sulfide concentration in laboratory oxidation ponds. Three tests were conducted with the same BOD surface load (136 lb BOD/acre/day) and the same detention time (15 days); the only difference was the concentration of sulfate ions in the influent. For the experimental laboratory facultative lagoon under controlled light and temperature conditions, a linear relationship was reported to exist between the average sulfide concentration in the pond and the influent sulfate concentration. The relationship obtained bears no value; however, this reduction depended on the sum total of all oxidation-reduction reactions occurring in the lagoon, as well as the amount of sulfide produced. Although this relationship is not definitive, the general correlation between sulfide production and ORP is observed.

Espino de la O and Gloyna (58) reported increases in sulfide concentrations in the pond from 0 to about 1 and 2 mg/l respectively, which were accompanied with drops in the ORP of about 80 to 120 mv; further increases in sulfide concentration affected ORP in a lesser way.

The effect of photosynthesis on the evolution of sulfide may be clearly observed. The change of sulfide concentration with time illustrated the importance of photosynthetic oxygenation; the sulfide concentration decreased sharply when the lights were turned on, and increased slowly after the lights were turned off. From these results, Espino de la 0 and Gloyna (58) concluded that, in the presence of dissolved oxygen concentrations in excess of about 1 mg/l, the sulfide concentration was negligible.

The actual severity of hydrogen sulfide odors evolved from a facultative lagoon is based upon the complex interactions between pH, ORP, and the presence or absence of dissolved oxygen under extended ice cover is the greatest. Break-up rapidly produces added oxygen, discharges carbon dixoide and elevates the pH. Problems associated with spring break-up, although they usually do not last long, are, however, ofter very severe.

Concerning the evolution of hydrogen sulfide as a limiting factor in oxidation pond failures, it is important to note that bacterial sulfide production is related to:

1. The sulfate concentration in the carriage water,
2. The organic loading rate, lb BOD/acre/day,
3. The sulfate loading rate, lb SO_4=/acre/day, and
4. The lagoon detention time.

It is evident from the preceding discussion that periodic obnoxious hydrogen sulfide odor failures are predictable based upon an understanding of the complex interactions of organic loading rate, sulfate loading rate, presence or absence of dissolved oxygen, water temperature, oxidation-reduction potential, and pH.

WATER LOSS

Lagoons need a certain depth of water to operate well. Exactly how much water is needed is debatable, but about 3-4 feet depth seems satisfactory in most places for facultative lagoons. Yet some lagoons have been built on ground so porous that they will not hold water. In addition to the lack of treatment wastes receive under these conditions, the potential for groundwater contamination is very real, and should be realized.

Colorado and Missouri require actual field measurements of percolation rates before construction or use of the lagoon is permitted. Florida will not permit the use of lagoons to treat raw sewage wastes due to groundwater contamination problems which have occurred in the past. The possibility of using a sealing technique on the bottom and sides of a new lagoon to reduce leakage is being considered more frequently now as states are beginning to realize the problem.

Evaporation from the surface of the lagoon will also cause a significant loss in some areas of the country. This evaporation loss must be incorporated in the lagoon design, or supplemental water may have to be provided to maintain proper operation.

It is interesting that many guideline documents (including the ten states' standards) indicate that percolation tests shall (must) be performed. The results of these tests may, however, be used to identify the adequacy of a particular site. This kind of language produces a meaningless exercise.

Problems associated with normal housekeeping are bank deterioration, bank weeds, floatable solids, emergent weeds and floating algal mats.

As presently designed, any of these problems can develop with unfortunate consequences. Minimal precautions and maintenance can alleviate most.

Grass cutting and weed removal not only make the area esthetically more pleasing - they reduce the living space for some noxious insects, (mainly Diptera).

Riprap has been employed to stabilize banks especially where strong prevailing winds tend to wash the offside bank. While this practice does stabilize the bank somewhat, it also provides hiding places for midges and mosquitoes. Insecticides might be employed here but the choice should be for non-persistent or degradable ones instead of the less expensive DDT or other chlorinated hydrocarbons. The propensity of algae to absorb these materials rapidly is well known, and could add to the stream load of such compounds.

Some state have tried concrete or asphalt aprons around the edge, above and below water level, to control weeds. These appear to work satisfactorily for a while, but will need maintenance as cracks develop.

Herbicides can be, and have been employed - but care must be exercised so that useful algae are not eliminated from the pond system. Use of these compounds by careless operators could have devastating effects on performance and on the receiving stream.

Smaller facilities without means of grinding or separating foreign matter, have been plagued by various rubber and plastic items. Inadequate fencing has resulted in many items of junk being thrown into these facilities as well. Floating algal mats can be mechanically dispersed, but it would appear to be more satisfactory to create conditions initially which would not foster their growth and accumulation.

Record Keeping and Reporting - Accurate and faithful reporting of performance is to be desired. Many of the currently employed measurements are of doubtful utility. The mere fact that any given water quality parameter may be easy to obtain does not, in itself, justify its use.

Influent and effluent flows are absolutely necessary to determine performance. These, coupled to a rapid, simple COD measurement technique of universal applicability, would appear to yield the most simple and useful measurements to determine operating performance.

The flagrant violations of sampling and reporting enumerated in this report are mute testimony to the lack of reliable data.

The poor quality record keeping observed can have far reaching consequences. For example, the contractor has recently viewed data in support of a multi-million dollar public works project where a 90% efficienty was attributed to every lagoon within a watershed. Many of these lagoons are presently badly overloaded. Fewer than half have filed reliable operating data; some have never filed any data. The figures, however, were used to calculate municipal waste loads for the project. Clearly, this kind of unintentioned error can only lead to poor quality water supplies and esthetically distasteful recreational facilities.

Sampling - The contractor's survey uncovered a marvelous array of printed forms and elaborated mechanisms for the reporting of lagoons (and other treatment) facilities. While it is true that most mechanical facilities (regardless of type) *may* have adequately trained personnel to conduct these measurements, it is equally true that most lagoon facilities *do not*. We found it almost impossible to accurately assess lagoon performance due to the universally bad record keeping practiced. What appears to be needed is not ten or twelve parameters which *can* be performed by an inexperienced or temporary operator, but rather 1 or 2 measurements which might be truly meaningful in assessing lagoon performance. What does it serve to have pH, D.O., M.O., or phenopthalein alkalinity, color, turbidity, relative stability, conductivity, and the like, if we lack information on influent and effluent volume and organic load? The contractor feels that all levels of government have been remiss in not providing workable, meaningful methods which could be implemented by semi-skilled personnel

Selective Effluent Discharge - Studies by King, et al, demonstrated that diurnal vertical migration of algae could alter the amount of organic matter discharged from a lagoon by at least four times. While the dissolved COD remained essentially constant at a relatively low level, the lowest levels between midnight and 6:00 a.m. King rightly suggests that this feature should be incorporated into any study where lagoon effluents are being monitored. We might add that selective draw-off or discharge at carefully chosen times and depths (midnight or 6:00 a.m., at about 12" depth) would insure an effluent low, or substantially lower in algal cells. This relatively simple act of utilizing existing data to increase effluent quality would appear to be much more suitable than more elaborate mechanical systems designed to remove algal cells. In effect, one would be working with a natural process rather than against it.

SECTION II

RECOMMENDATIONS

The previous section discussed problems of lagoons; this section will provide recommendations for improving at least some of the problems of lagoon performance.

1. Hydraulic overloading can be corrected by expansion of facilities so that the waste can be detained long enough to receive treatment.

2. Organic overloading has been overcome at times by installation of aeration devices to supply additional oxygen to treat the wastes. Either mechanical contact aerators or diffused air systems can be used.

3. The biggest problem most characteristic of lagoons is short-circuiting. Short-circuiting as discussed in section I is almost guaranteed by the design called for in the Ten State Standards and other basin design standards. Placing of baffles in the cells, constructing long, narrow cells, multiple cell installations, or providing for recirculation of a portion of the effluent can all reduce short-circuiting.

4. The inclusion of pond bottom diffusers acting as an air screen would accomplish two objectives: (1) add additional oxygen; and (2) act as an effective barrier to unimpeded short-circuiting. This would appear to meet the objection of structures which would collect solids, fat and grease.

5. A deep primary lagoon cell could be provided to insure anaerobic conditions for decomposing the raw sewage more rapidly and for settling of solids.

6. A baffled aerobic zone would provide stabilization of the effluent and promote algae growth if desired. Such a section could also be aerated for more controlled oxygen uses.

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7. An area without baffles is desirable near the effluent collector to allow settling of solids.

8. The effluent collection system should be a set of weirs to collect over a large area at a slow rate.

9. Algae removal systems should be studied in detail in a research project, but some possible systems are: (1) chlorination followed by rapid sand filtration with backwash returned to the anaerobic zone of the first lagoon; (2) microorganisms such as Daphnia in a separate cell to eat the algae; (This is currently being done experimentally in Texas.) (3) fish to eat algae or organisms which consume algae; and (4) screening techniques with chemical pretreatment if needed to coagulate the algae into aggregates large enough to be captured by the screens.

10. Suggestions that chlorination of effluent and the subsequent killings of algal cells does not degrade stream quality is unsupported. Clearly, the impact of chlorination of lagoon effluents requires further study.

11. The concept of selective level effluent drawoff should be investigated for minimizing algal cell concentrations in the lagoon effluent.

12. The monitoring of lagoon influent and effluent flow plus some measure of organic loading are essential to adequate lagoon monitoring.

13. The basis for improved lagoon operation should include the use of a reliable "yardstick" such as influent and effluent flow-measurement together with Chemical Oxygen Demand (COD), suspended solids or organic carbon measurements in place of a wide variety of parameters such as DO, pH and BOD.

14. The installation of a management system at the state level to insure reliable reporting of lagoon performance would prevent careless and thoughtless record keeping.

15. Annual or bi-annual certification and re-licensing of lagoon facilities and operators is recommended. This could alleviate lagoon failures due to overloaded conditions and poor operating practices.

16. Effective stream monitoring is recommended to determine the full extent of potential degradation due to the discharge of lagoon effluents.

17. Small lagoon installations are potentially as damaging as larger ones. All must be brought under effective engineering design, operation and maintenance.

18. An improved lagoon design and operation manual is recommended in order to consider present water quality and recommended treatment criteria and advances in lagoon technology in place of "passive" design standards.

SECTION III

INTRODUCTION

PROBLEM

Projected population increases, industrial expansion, and increased per capita water use are responsible for the growing concern about water quality and the effectiveness of present treatment systems to satisfactorily remove pollutants. The quality of receiving streams cannot be maintained or upgraded unless pollutants in waste streams are removed prior to their discharge to the aquatic ecosystem.

Recent investigations have indicated that lagoon effluent quality is not equivalent to secondary treatment standards and, as a result, lagoon effluents do not contribute to the restoration or maintenance of receiving water quality (11) (7) (36) This report is designed to assess the magnitude and extent of this problem by reporting on lagoon performance and the state of lagoon technology. The contractor made more than 500 contracts and reviewed available literature to generate the required data base for this study.

EXTENT AND USE OF LAGOONS

Lagoons have gained widespread use in the last twenty-five years as a waste treatment process. Figure 1 illustrates the rapid growth in the number of lagoons treating municipal wastewater in the United States. The inventory is based upon data collected by RETA in 1970-1971; by the Federal Water Quality Administration in 1968; and by the Public Health Service in 1962, 1957, 1945 and 1940 (1). In 1945, it was estimated that 45 lagoons were treating municipal wastewater. In the subsequent 15 years the number of lagoons increased by two orders of magnitude to 4,476.

In certain states STORET (2) data reported less than one-third of the total number of lagoons inventoried by RETA. This difference is indicated in Figure 2, which shows the geographic distribution and number of lagoons treating municipal waste by state, and the general attitude of that state toward lagoons. Two numbers are shown inside each

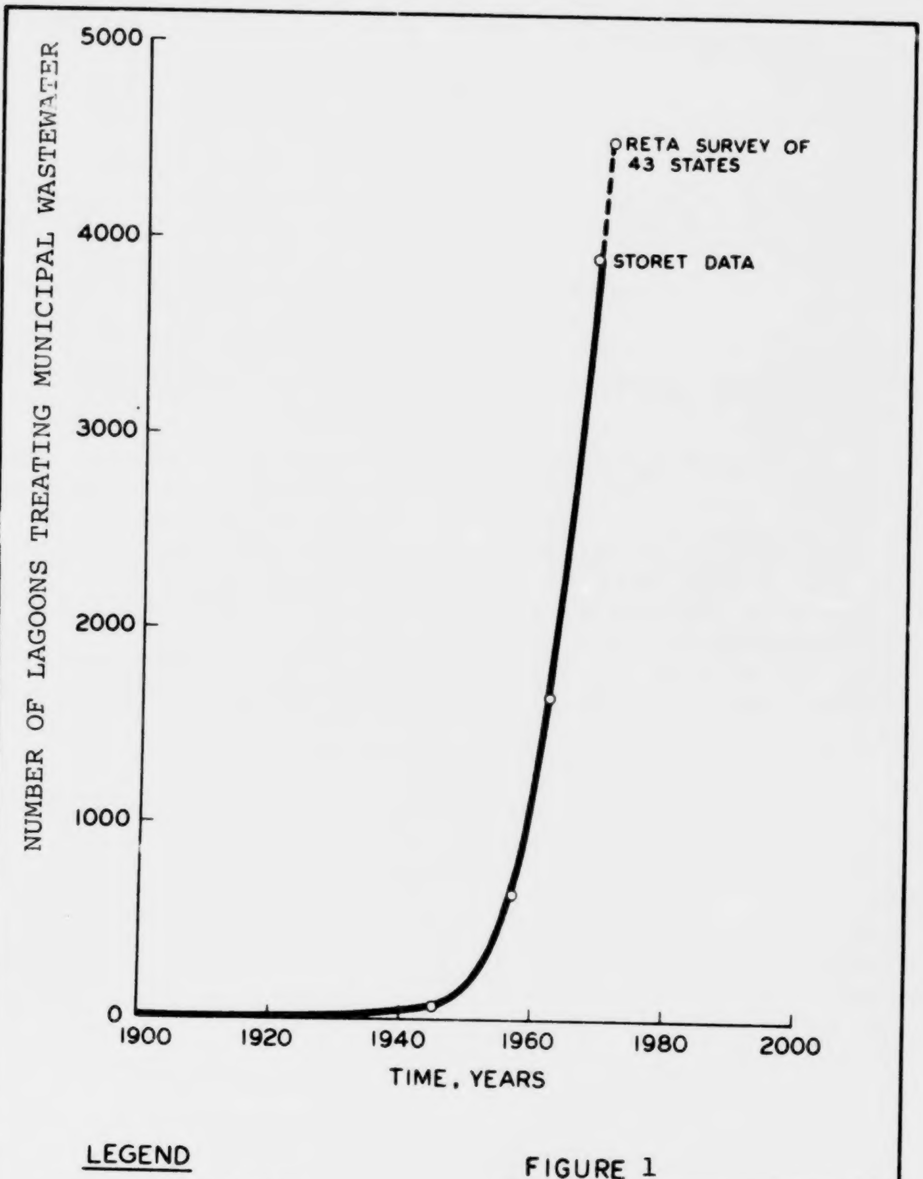
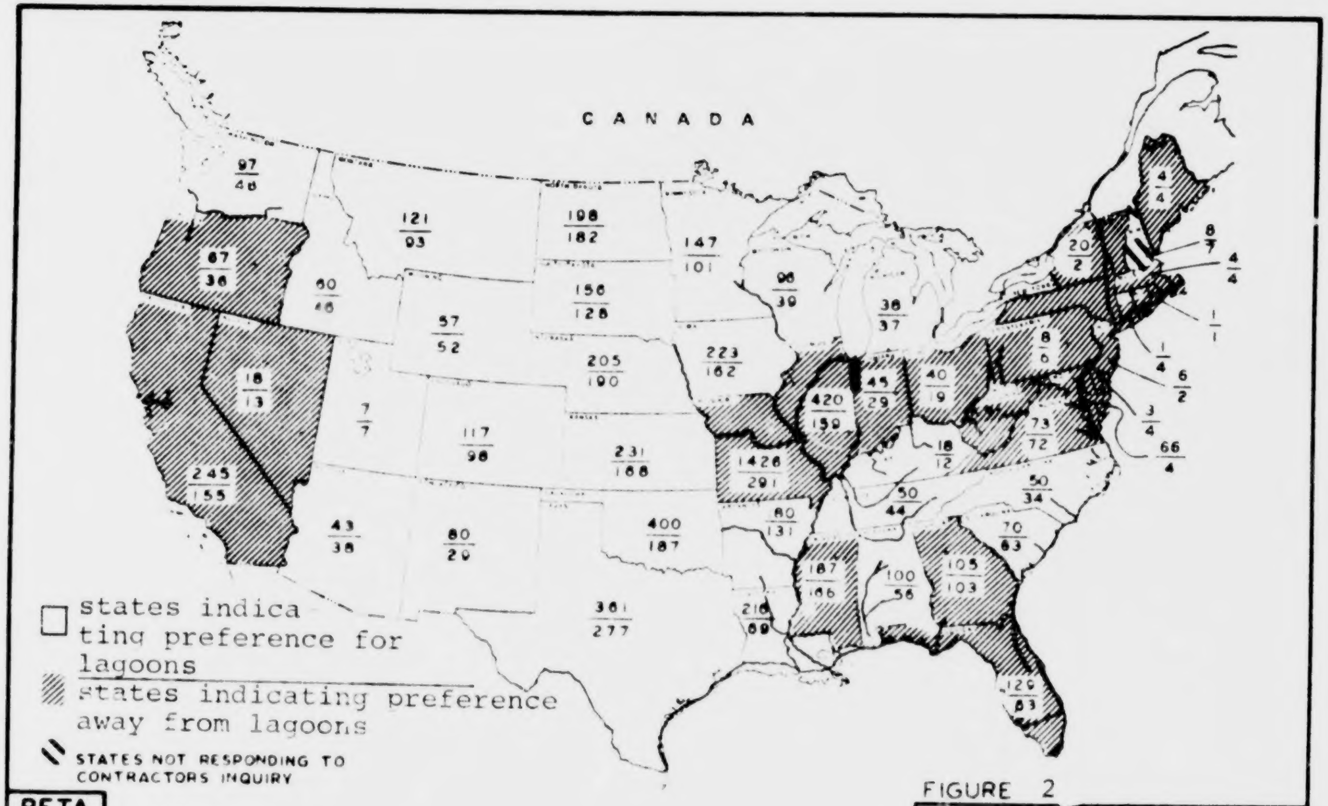


FIGURE 1

EXTENT OF MUNICIPAL LAGOON USE FOR WASTEWATER TREATMENT IN THE UNITED STATES



CANADA
97/48
87/36
60/48
121/93
198/182
147/101
98/39
38/37
4/4
20/2
8/7
4/4
1/1
18/13
57/52
156/128
223/162
8/6
1/4
6/2
7/7
117/98
205/190
420/159
45/29
40/19
73/72
3/4
66/4
245/155
231/168
1428/291
18/12
50/34
43/38
80/29
400/187
80/131
50/44
70/63
361/277
216/69
187/166
100/56
105/103
129/83

□ states indicating preference for lagoons

▨ states indicating preference away from lagoons

STATES NOT RESPONDING TO CONTRACTORS INQUIRY

RETA 851

NUMBER KEY

# MUNICIPAL LAGOONS FOUND BY CONTRACTOR SURVEY

# LAGOONS IN 1968 STORET SURVEY

FIGURE 2

EXTENT, USE AND ACCEPTANCE OF MUNICIPAL LAGOONS state: the top figure indicates the number of lagoons inventoried by the contractor in 1971, the bottom figure represents the number of lagoons reported in the 1968 FWQA inventory (3).

According to the 1971 inventory, there was a total of 4,476 municipal lagoons in use in the United States. New lagoon construction and incomplete reporting are responsible for the variance between 1968 and 1971 figures. In reality, both figures are far too low, since the number of private lagoons has not been taken into account. These private installations, which serve individual homes, trailer parks, schools, shopping centers, gas stations, and other facilities are difficult to inventory. Examination of these installations by state officials is extremely rare and few records of any kind are maintained. In states such as Missouri and Kansas where private lagoons are quite popular, there may be several thousand installations not subject to examination or survey.

The contractor's survey indicates that lagoons initially serve small or newly emerging communities. When population increases, lagoon performance in these communities gradually deteriorates until operations reach intolerable proportions. IT IS IMPORTANT TO NOTE THAT IN AREAS SUCH AS CALIFORNIA, MISSOURI, ILLINOIS, VIRGINIA, MISSISSIPPI, GEORGIA, AND FLORIDA, WHERE LAGOONS ARE IN HEAVY USE, THEY ARE NOT WELL LIKED. These attitudes resulted from recent operational problems that were either unknown or nonexistent when the service area was less populated.

To small or emerging population centers, lagoons are economically attractive. While initial capital construction costs are not high, Federal construction funds are available. In addition, operating and maintenance costs are lower for lagoons than for mechanical treatment plants. Thus, lagoon treatment is satisfactory to small or emerging communities because of its lower costs, although lagoon performance, associated with the production of green effluent and odors, is not of the highest quality.

A discrepancy exists between the intended goal of waste treatment to improve receiving water quality and the actual effect on receiving streams where lagoons are used. Small or emerging communities located along small receiving streams of relatively high water quality have low flow and little or no dilution capacity. Thus, these streams require the highest possible effluent quality. However, because these communities can only afford a minimal form of waste treatment, quality effluent cannot be insured. As communities increase in population, and lagoons continue to be used for waste treatment, the receiving water quality may be further jeopardized.

PROJECT OBJECTIVES

An extensive literature review has not disclosed any evaluation of lagoon performance based upon water quality criteria or effluent standards; such an evaluation is critical in determining where lagoons can provide adequate treatment or, in small or emerging communities, how their performance and effluent quality can be improved. The effectiveness of lagoons in providing secondary treatment to contribute to the restoration and maintenance of receiving water quality can be accomplished by:

1. Evaluating and criticizing the Proceedings of the Second International Symposium for Waste Treatment Lagoons.

2. Reporting on the adequacy of lagoons to provide equivalent secondary treatment.

3. Collecting the most recent reliable inventory data defining the extent and use of lagoons treating municipal wastewater and the present investment in them.

4. Collecting and evaluating all recent reliable lagoon operating data.

5. Evaluating the effect of lagoon effluents on receiving water quality.

6. Reporting on the adequacy of lagoon effluent quality in relation to effluent and water quality standards.

7. Reporting discussions with key state engineers and their evaluation of the adequacy of lagoon performance.

8. Reporting the problems and limiting factors of lagoons.

9. Reporting on the procedures and research required to upgrade lagoon performance.

10. Assessing the accuracy of current lagoon effluent quality reporting systems.

PROJECT SCOPE

The following scope of work defines the framework, procedures, data sources, and criteria for obtaining information.

1. The investigation will be confined to domestic sewage lagoons of the following types:

Facultative
Aerated - Facultative
Complete-mix Aerobic
Anaerobic
Tertiary
Oxidation Ditches

2. The project will rely entirely upon the existing data base.

3. Data sources will be confined to only the most recent reliable lagoon field operations.

4. The study will be directed at obtaining representative lagoon performance data in the contiguous United States.

5. Where available, the following performance criteria will be considered:

Effluent Quality

BOD
COD
SS
Settleable Solids
Floatable Solids
Phosphorus
Nitrogen
Algae
Coliform

Aesthetic Quality

H_2S Odors

Algae Mats
Pig-Pen Odors
Short Growth (Weeds)
Insect and Rodent Breeding
Green Effluent
Appearance

6. Lagoon performance will be evaluated against:

Receiving water quality criteria
Effluent quality standards
Definitions of secondary treatment

CLASSIFICATION OF LAGOONS

More than 10 years ago at the First Lagoon Symposium, D. F. Smallhorst (4) indicated the need for standardization of lagoon terminology; this need still exists.

The terms describing man-made ponds for the treatment of wastes include lagoon, sewage lagoon, waste treatment lagoon, stabilization lagoon, waste-stabilization lagoon, waste pond, oxidation pond, stabilization pond, and waste stabilization pond. Such prefixes as "anaerobic", "aerobic", "facultative", "aerated", "sludge" and "manure" are also applied.

Although a general classification scheme has been developed, the American Society of Civil Engineers Sewage Treatment Design Manual (59) has recognized that none of the following classifications describes the stabilization ponds in use. The exact nature of lagoons and their classification may vary due to seasonal environmental fluctuations. Based upon use, operation, design and physical, chemical and biological observations, lagoons have been classified according to depth, main source of oxygen, rate of organic loading per day, inlet, flow-through and inlet-outlet arrangements, recirculation schemes, and method of effluent disposal by percolation, evaporation, or transpiration from cover crops.

Facultative oxidation lagoons have been described by Caldwell (5), Van Heuvelen and Svore (6), King (7), and by Herman and Gloyna (8). They are usually 3 to 5 feet liquid deep and receive organic loadings of 10 to 100 pounds of BOD_5 per acre per day (lb BOD/acre/day); average detention time is approximately 40 days. Facultative lagoons are characterized by oxygen stratification, with an anaerobic layer below an aerobic layer; settleable solids are deposited on the bottom and undergo anaerobic decomposition. Photosynthetic oxygenation, operative in the surface layer during daylight hours, is the prime source of oxygen in facultative lagoons. Mechanical aeration equipment is not a part of conventional single or multi-celled facultative lagoons. Influent is raw or primary settled sewage.

The aerated facultative lagoon has been described by O'Connor and Eckenfelder (9), Eckenfelder (10), McKinney and Eddy (11), and McWhirter (12). Supplemental aeration is employed in facultative lagoons to relieve organic overload, to reduce time of treatment, or to reduce odor complaints. Organic loadings of 10 to 300 lb BOD/acre/day are common. Lagoon detention time ranges from 1 or 2 to 30 days. Aerated facultative lagoons are usually not stratified because of increased vertical mixing attributable to the supplemental aeration system. The heavy solids settle to the bottom and undergo anaerobic decomposition; the balance of influent organics are stabilized aerobically. Oxygen is provided by the supplemental aeration system and by photo-synthetic oxygenation, although the latter is reduced due to increased lagoon turbidity.

Complete-mix aerobic lagoons have been described by McKinney (13), Sawyer (14), and Burkhead and McKinney (15). In complete-mix aerobic lagoons, solids remain suspended and are stabilized aerobically. These lagoons are usually 8 to 10 feet deep and receive organic loadings in excess of 100 lb BOD/acre/day. The average lagoon detention time is approximately 2 to 7 days. Photosynthetic oxygenation is reduced due to complete lagoon solids suspension. Aerobic stabilization is dependent on the supplemental aeration system for dissolved oxygen.

The objective of high-rate aerobic lagoons is microbial conversion of organic wastes into algae. These lagoons have been described by Oswald and Gotaas (16) and Oswald (17). High-rate lagoons usually have a liquid depth of 1 to 2 feet and receive organic loadings of 100 to 200 lb BOD/acre/day; their average detention time ranges from 2 to 6 days. High-rate lagoons are well mixed, usually mechanically. Oxygen is provided photosythetically and atmospheric reaeration is usually not significant.

Anaerobic lagoons have been described by Parker, et al., (19), Parker et al., (20), Loehr (21), and von Eck and Simpson (22). Anaerobic lagoons are built with a small surface area and a usual liquid depth of 8 to 10 feet. Anaerobic lagoons are comparable to single-stage, unmixed, unheated digesters. Organic loadings are from 0.36 to 10.4 pounds of volatile solids per day per 1,000 ft^3 (lb VS/day/ 1,000 ft^3); however, loadings as high as 132 to 320 have been used successfully (18). The average anaerobic lagoon detention time is 1 to 7 days.

In anaerobic lagoons, there is a relatively solids-free liquid layer above a layer of settled solids. A floating scum layer will occur depending upon the nature of the waste. Anaerobic lagoons are most effective with highly concentrated organic wastes.

Increased emphasis is being placed on tertiary methods of treatment to remove greater amounts of polluting elements still present in the effluents of secondary treatment processes. Tertiary lagoons have been proposed to reduce BOD, suspended solids, coliform count, nitrogen and phosphorus. Facultative, aerated facultative and aerobic tertiary lagoons have been described in the literature by Loehr and Stephenson (23) and Weiss (24). Organic loadings of secondary biologically treated effluents range from 10 to 700 (lb BOD/acre/day). The average tertiary lagoon retention time ranges from one day to several weeks. The depth of tertiary lagoons varies from 1 to 5 feet. Oxygen is supplied photosynthetically and from supplemental aeration. Stratification may or may not occur depending on the degree of vertical mixing.

These lagoon classifications described above are used throughout this report. The contractor recommends that these definitions, or modifications be adopted by EPA and used in all research and construction grant activities.

SECTION IV

STATE PROGRAMS

INTRODUCTION

In conjunction with this study, the contractor has contacted State Health Departments, State Water Pollution Control Authorities, State Water Quality Control Commissions, State Environmental Improvement Divisions, State Environmental Protection Agencies, State Departments of Environmental Resources, and major universities. The contractor made more than 500 contacts and reviewed published articles and reports in generating the data base required to define lagoon performance and the state of lagoon technology. A complete list of information sources, contacts and correspondence is included in Appendix A. Detailed state evaluations are included in Appendix D. The data and results collected in the state-wide investigations are detailed in this chapter, including the following objectives:

1. What is the evaluation of state engineers on the adequacy of lagoons to provide secondary treatment?

2. Is there a difference between BOD design loadings and actual BOD loading being applied to lagoons?

3. What are the performance problems with lagoons as reported by state engineers?

4. What lagoon performance parameters are being monitored and reported and at what frequency?

SUMMARY OF CONTRACTOR'S EVALUATION OF STATE PROGRAMS

When asked to evaluate lagoons as a treatment system, State Health Departments and Water Pollution Control Agencies contributed a diversity of opinions. In states such as South Dakota lagoons are considered the best treatment process. By contrast, Florida does not permit raw sewage lagoons and uses lagoons only as polishing ponds after secondary treatment. Texas formerly referred to lagoons as "temporary" treatment systems, and requires primary treatment before lagoons. About 85 percent of lagoon treatment in Texas is preceded by a mechanical primary system,

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according to the data Texas made available to the contractor.

In general, it is apparent that lagoons east of the Mississippi River do not provide adequate treatment. Climatic conditions including temperature, rainfall and evaporation contribute to a less than satisfactory performance picture. While algae and odor problems seem to be the most frequent complaints about lagoons, fluctuating effluent quality is also a problem. No state engineers cited short-circuiting as a problem, although some conceded during personal contacts that short-circuiting did occur; validated published investigations verify that short-circuiting is a major problem of lagoons.

Contact with state engineers illustrated the degree to which states are ignorant of lagoon performance. Only minor and infrequent sampling is required and data **are** provided even less frequently than requested. In Missouri, about 40 percent of the lagoons file no data with the state; Those who do file frequently do not include information on one or more of the required parameters. Those measurements most frequently omitted were BOD of effluent, flow, DO and BOD, and DO of the receiving stream above and below the plant out-fall. These were not just occasional missing records: records document that a plant either tends to report regularly or not at all.

Most lagoon data are based primarily on physical observation. Analytical results are scattered and of limited reliability although state engineers were unconcerned and still felt able to evaluate lagoon performance. These evaluations are discussed on a state-by-state basis in Appendix D.

Both Illinois and Texas have computerized treatment plant data, although at this time neither can produce an in depth print-out record on any plant or on one type of plant, such as lagoons. Efforts are being made to create such programs, and reportedly should be completed soon. Both these states have survey crews who periodically sample effluent on a grab basis. In addition, Texas computerizes monthly results from treatment plants with the "Texas Self-Reporting System." In this program, the operator fills in a form each month, listing peak and average results of all measurements required for his installation. This program could serve as a model for other states: if a plant is experiencing difficulty, this reporting system uncovers any trouble and allows corrective action.

The contractor felt the following attitude was most prevalent among the state engineers surveyed: "As long as no one complains about a lagoon, we won't do anything about it." Most states surveyed indicated that lagoons provide secondary treatment, and it is clear that in many states lagoons are defined as secondary treatment regardless of the performance they give. Thus, as defined under these conditions, lagoons must meet requirements for secondary treatment.

This information demonstrates the regrettable state of lagoon wastewater treatment; of those experts surveyed in this field most lacked knowledge about actual lagoon treatment and performance conditions.

STATE ENGINEERS EVALUATION OF THE ADEQUACY OF LAGOONS TO PROVIDE SECONDARY TREATMENT

All states were asked to evaluate lagoons as an equivalent secondary treatment process. These results, shown in Table 2, are summarized below:

STATE ENGINEERS EVALUATION

Number of States Reporting	Are Lagoons Considered Equivalent Secondary Treatment		
	Yes	No	Depends
50	24	18	8

In twenty-four states lagoons were equivalent to secondary treatment while in eighteen they were not. Eight states reported lagoons were considered equivalent secondary treatment, albeit depending on specific conditions.

It should be noted that about 60 percent of all lagoons are located in states not considering lagoons as secondary

Table 2

STATE ENGINEERS' EVALUATION OF THE
ADEQUACY OF LAGOONS TO PROVIDE SECONDARY TREATMENT

State	Are Lagoons Equivalent to Secondary Treatment?	Comments
Alabama	Yes	
Alaska	Yes	
Arizona	Yes	Well suited to climate; effluent used for irrigation.
Arkansas	Yes	Low cost, ease of maintenance important.
California	Qualified Yes	Lagoons limited in treatment ability. Acceptable for small installations.
Colorado	Yes	Lagoons work well in Colorado.
Connecticut	No	Limited use.
Delaware	No	Limited use.
Florida	No	Used only for polishing secondary effluent.
Georgia	Qualified Yes	Use depends on receiving stream.
Hawaii		
Idaho	Yes	
Illinois	Qualified Yes	Need 3 cells to meet effluent standards. OK if meet the standards.
Indiana	No	Receiving stream can't handle effluent.
Iowa	Yes	Recommend for less than 10,000 P.E.
Kansas	Yes	
Kentucky	Yes	
Louisiana	Yes	
Maine	No	Limited use.
Maryland	Yes	
Massachusetts	No	
Michigan	Yes	Discharge permitted only in spring and fall. Samples required before discharge.
Minnesota	Yes	Discharge permitted spring and fall.
Mississippi	No	BOD not removed due to algae growth.
Missouri	No	
Montana	Yes	May restrict winter discharges.
Nebraska	Yes	Best method for small communities.
Nevada	No	
New Hampshire	No	Limited use.
New Jersey	No	Limited use.
New Mexico	Yes	
New York	Qualified Yes	
North Carolina	Qualified Yes	Not necessarily choose over conventional plants.
North Dakota	Yes	Best cold weather treatment system devised. Control discharge.
Ohio	No	
Oklahoma	Qualified Yes	
Oregon	No	
Pennsylvania	No	
Rhode Island	No	Not widely used.
South Carolina	Yes	
South Dakota	Yes	For small communities.
Tennessee	Yes	For small communities.
Texas	Yes	For small communities.
Utah	Yes	
Vermont	No	Limited use.
Virginia	Qualified Yes	Stream standards not met in winter.
Washington	Qualified Yes	Effluent must not be a detriment to receiving water quality.
West Virginia	No	
Wisconsin	Yes	
Wyoming	Yes	

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treatment or where their use is dependent on specific conditions. In approximately half of these states severe lagoon failures have been responsible for changed attitudes among leading state engineers with regard to the adequacy of lagoon treatment.

Lagoons are located in all states which receive raw or primary settled municipal wastewater. Even though lagoons are not considered equivalent secondary treatment by 18 state engineers, they are still being constructed in these states for this purpose and are receiving state endorsement.

STATE ENGINEERS REPORT OF LAGOON DESIGN AND ACTUAL BOD LOADINGS

The literature is replete with papers presenting advanced techniques for design of lagoons. Most state design manuals, however, remain based on lb BOD_5/acre/day or lb/BOD_5/1000 ft^3. Canter and Englande (25), and Dildine and Franzmathes (26) have reported BOD design loadings of the 50 states. These values are shown in Table 3 along with design loadings determined in the contractor's survey of state engineers. The design loadings from these three sources are fairly uniform and there is little to be learned from this evaluation. However, in 49 states, state engineers reported no periodic required measurement of actual BOD loadings. Arkansas measures actual BOD loadings once each year.

Design criteria, while useful, are of little value to the growing community confronted with lagoon failures of effluent and aesthetic quality. It should be mandatory for communities to periodically monitor and report influent characteristics and organic loadings of lagoons. States should demand and enforce this action. When design loadings are reached sewer "hook-ups" should not be allowed until the treatment facilities are expanded.

STATE ENGINEERS REPORT OF LAGOON PERFORMANCE AESTHETIC PROBLEMS

Americans are becoming increasingly concerned with the aesthetic quality of the physical environment. Aesthetic expectations will probably rise with increases in education and leisure time. The primary goal of waste treatment must be to provide an environment that is pleasing as well

Table 3

[illegible]

State	[illegible] Contractor	[illegible] & Franz-Mathes Report	Canter & Englande Report	Does State Require Periodic Measuring & Reporting Actual BOD Loading	Comments
Alabama	50	50	50	No	
Alaska	--	--	20	No	
Arizona	50	50	50	No	
Arkansas	30	30	30	Yes	Measured on rotating basis by the state.
California	--	--	--	No	
Colorado	0.1 #/ 1000 Ft^3	21.8	17.4	No	
Connecticut	--	--	--	No	
Delaware	--	--	--	No	
Florida	10-12 (1) 50 (2)	12 - 50	--	No	(1) Evaporative (2) Polishing
Georgia	35-50	35	50	No	
Hawaii	--	--	50	No	
Idaho	22-34	22-34	22	No	
Illinois	10 St. Stds.	22-30	26	No	
Indiana	--	--	22	No	
Iowa	10 St. Stds.	--	20	No	
Kansas	35	35	34	No	
Kentucky	20	--	22.8	No	
Louisiana	--	--	50	No	
Maine	--	20-35	--	No	
Maryland	35	35	35	No	
Massachusetts	--	--	--	No	
Michigan	6 Mo. Detention	--	20	No	
Minnesota	20 + 180 Day Det.	--	20	No	
Mississippi		--	50	No	
Missouri	34 (1) 45	45	45	No	(1) All receiving waters except Missouri, lower Miss.
Montana	18-20	18-20	20	No	
Nebraska	25	25	25	No	
Nevada	--	--	50	No	
New Hampshire	--	35	35	No	
New Jersey	--	--	--	No	
New Mexico	--	--	35	No	
New York	0.5# 1000 Ft^3	--	22	No	
North Carolina	50	50	50	No	
North Dakota	30	30	20	No	
Ohio	10 St. Stds.	34	33.4	No	
Oklahoma	30	30	30	No	
Oregon	--	35	35	No	
Pennsylvania	22	22	22.8	No	
Rhode Island	--	--	--	No	
South Carolina	50	50	50	No	
South Dakota	17	17	21.8	No	
Tennessee	34	34	33	No	
Texas	35 overall	75 1st cell 35 overall	50	No	
Utah	--	40	40	No	
Vermont	40	20	20	No	
Virginia	34	80	80	No	
Washington	--	40-50	40	No	
West Virginia	34	34	34	No	
Wisconsin	--	--	16.7	No	
Wyoming	17	20	35	No	

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as healthy (27). Periodic aesthetic failures of lagoons resulting in hydrogen sulfide odors, malodorous algae blooms, mosquito breeding, highly colored effluents, or septic sewage odors degrade aesthetic qualities and appreciation.

To evaluate the prevalence of aesthetic and performance failures, the contractor conducted a 50-state survey. the results, shown in Table 4, are summarized below.

SUMMARY OF LAGOON AESTHETIC AND PERFORMANCE PROBLEMS

	Type of Problem				
	Odor	Algae in Effluent	Short-Circulating	Organic Overload	Poor Effluent
Number of States Reporting Problem	50	21	23	6	20

Odor failures were reported in all states at some time during the year. Odors were usually present during spring and fall turnover due to the presence of hydrogen sulfide, or during summer from malodorus algae blooms.

Twenty-one states reported algae in the effluent as a problem; the remaining 29 states either failed to respond or indicated algae in effluent was not a problem.

Lagoon short-circuiting was reported in 23 states. The remaining 27 states did not know if lagoons experienced short-circuiting. As discussed in Section I every published report on lagoon short-circuiting indicates this as a serious problem. Where states did not report short-circuiting, there usually were no measurements made and, therefore, no basis for judgment.

Organically overloaded lagoons were reported in only seven states. If these data are correct it would appear that

Table 4

MUNICIPAL WASTEWATER LAGOON PROBLEMS
REPORTED BY STATE ENGINEERS

State	Odors	Algae in Effluent	Short Circuiting	Organic Overload	Poor Effluent
Alabama	X				
Alaska	X				
Arizona	X				X
Arkansas	X	X	X		
California	X		X		X
Colorado	X				
Connecticut	X				
Delaware	X				
Florida	X	X	X		
Georgia	X	X	X	X	
Hawaii	X				
Idaho	X	X			X
Illinois	X	X	X		X
Indiana	X	X	X		X
Iowa	X	X	X	X	X
Kansas	X				
Kentucky	X	X	X		
Louisiana	X		X		
Maine	X				
Maryland	X			X	
Massachuset	X				X
Michigan	X				X
Minnesota	X	X			
Mississippi	X	X	X		X
Missouri	X	X	X	X	X
Montana	X	X			X
Nebraska	X	X	X		
Nevada	X				
New Hampshire	X				
New Jersey	X				
New Mexico	X				
New York	X		X		X
North Carolina	X	X	X		
North Dakota	X				
Ohio	X	X	X		X
Oklahoma	X	X	X		X
Oregon	X				
Pennsylvania	X				X
Rhode Island	X				
South Carolina	X	X	X		
South Dakota	X	X			X
Tennessee	X	X	X		
Texas	X	X	X		X
Utah	X				
Vermont	X				
Virginia	X		X		
Washington	X		X		X
West Virginia	X		X	X	X
Wisconsin	X	X	X		
Wyoming	X			X	X

organic overload is not a serious problem. In the contractor's judgment, however, organic overload is one of the most serious problems confronting lagoon use. Why then was this not reported? For one basic reason -- the actual BOD loading of lagoons is not monitored. Validation of organically overloaded lagoons should be part of a field investigation of actual lagoon performance.

Twenty states reported poor effluent quality; the remaining 30 states either were satisfied with lagoon effluent quality or did not respond. This information is also misleading: although most states require periodic submission of lagoon effluent data, this request is seldom filled. Thus, state engineers have no bases or standards to judge the adequacy of effluent quality.

LAGOON PERFORMANCE PARAMETERS MONITORED BY STATES AND REPORTING FREQUENCY

In an effort to collect and evaluate all existing validated data, the contractor requested information on the presence and availability of lagoon influent and effluent data from all the states. The results of this inquiry, shown in Table 5, are summarized below.

NUMBER OF STATES REQUIRING LAGOON PERFORMANCE DATA

Waste Stream	Number of States Requiring Performance data	Number of States Not requiring Data	Number of States Not Responding
Influent	3	30	17
Effluent	28	5	17

Only three states, reported any collection of influent data and only 28 states reported monitoring of effluent parameters. To compound the situation, the frequency of

Table 5

LAGOON PERFORMANCE PARAMETERS
MONITORED BY STATES AND REPORTING FREQUENCY

State	Parameters Sampled Influent	 Effluent	Frequency
Alabama			
Alaska			
Arizona			
Arkansas		BOD	Infrequent
California		BOD, SS, Coliform	1X/Yr.
Colorado		Regionally Set	At least 2X/Yr.
Connecticut	BOD, Coliform, TSS	BOD, Coliform, TSS	Monthly
Delaware			
Florida		BOD, SS, Coliform	Monthly for polishing ponds
Georgia			
Hawaii			Monthly
Idaho		BOD, SS	2-3X/Yr.
Illinois		BOD, SS	
Indiana		BOD	Weekly
Iowa		D.O., Depth Flow	Daily
Kansas		D.O., Rel. Stab.	Monthly
Kentucky			Not Required
Louisiana		BOD	2X/Yr.
Maine			Not Required
Maryland			
Massachusetts		BOD, Coliform	4X . . or Less
Michigan		BOD, SS, pH, PO_4, Coliform	Before, during discharge
Minnesota	BOD	BOD, Coliform	Monthly
Mississippi			Not Required
Missouri	BOD	BOD, pH, D.O., Alk.	Monthly to bimonthly
Montana		BOD, SS	River basin annual reports
Nebraska			
Nevada			None
New Hampshire			
New Jersey			
New Mexico			
New York		BOD	1X every 2-3 yrs.
North Carolina		BOD	Monthly
North Dakota			
Ohio		PO_4, NO_3	Before discharge
Oklahoma		BOD	Weekly to daily
Oregon		BOD, SS	1-2X/Mo.
Pennsylvania			
Rhode Island		BOD, SS, Coliform	1-2X/Yr.
South Carolina			
South Dakota		BOD, SS, pH, Alk., D.O.	Less than 3X/Yr.
Tennessee		BOD	During discharge
Texas		BOD, SS, Cl_2 Res. Flow, BOD, SS, Set. Sol., Stability	2X/Mo. Monthly
Utah			
Vermont			
Virginia			
Washington			None
West Virginia		BOD	
Wisconsin		BOD, D.O., PO_4, Coliform	Monthly check of streams 1-2X/Yr.
Wyoming		BOD	Irregular

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data collection required by the states, as shown in Table 5 and summarized below, is totally inadequate for quality control, statistical accuracy or treatment process control.

FREQUENCY OF EFFLUENT DATA REPORTING REQUIRED BY STATES

Frequency of Reports Required by States						
None	Daily	Weekly	Monthly	Yearly	Other	Not Responding
5	2	2	9	9	6	17

Of the 33 states responding, five states require no data; data are required daily in two states, weekly in two, monthly in nine, and yearly in nine. In addition to these appalling facts, the contractor determined the following: (1) influent measurements are virtually unheard of; (2) even these meager report requests are not met; and (3) data submitted is often "dry-labed."

It is apparent through field investigations that a considerable difference exists between report requirements on lagoon performance and reports submitted to a regulatory agency. In Missouri, for example, all municipal waste treatment facilities are required to submit monthly operating reports, but there are no reports for about one-third of these facilities.

Similar situations were found in all the states studied. Where data were available, they were often of minimal value. Computer print-outs in Illinois failed to classify data by treatment facility or location so laboratory studies of stream effluent revealed little information. At present, this process is being changed to enable retrieval by treatment facility.

Texas has two reporting systems on treatment facility performance. The state-operated Texas Water Quality Board Audit contains results of state-conducted analyses and select design information on treatment facilities. In the

Texas "self-reporting system," a computerized collection and retrieval system of monthly operating data from each facility, operators are responsible for providing average and peak values for various required paramenters, depending on plant size. This system presents data for each facility for the past 12 months. However, since there is no influent BOD recorded, it is impossible to measure loading or treatment efficiency.

The Arkansas testing procedures produce excellent results for a specific study period but do not provide a representative sample. All treatment facilities in a drainage basin are extensively tested for four to seven days; influent and effluent concentrations and flow are measured on a rotating basis, with 80 percent of the treatment facilities tested each year.

It is clear from the contractor's investigation that a recommended sampling program and sampling frequency are imperative. These should be developed by the Federal EPA and required of the states through appropriate procedure.

SECTION V

CRITIQUE OF THE SECOND INTERNATIONAL SYMPOSIUM FOR WASTE TREATMENT LAGOONS

SUMMARY CRITIQUE

This chapter contains a critique of the Second International Symposium proceedings and a report on the attitudes and mood of Symposium participants.

During the course of this contract, design criteria or statements have been received from forty-five states. The Ten State Standards (28), other basin standards, or some minor modification of these standards are most commonly used as design criteria. None of these standards reflects an understanding of the technological advances presented at the Second International Symposium or even those presented at the First International Symposium; nor has there been an attempt by any state to implement these technological advances.

Despite the rhetoric, lagoons have continued to be offered and used as a panacea for wastewater treatment in many states.

The symposia have not been a catalyst to change operations in minimizing short-circuiting or removing algae. In this sense, their great potential has been unrealized. As demonstrated at the Second Symposium, the time is past for discussion about lagoons; solid engineering is needed to put principles into practice and lagoons in their proper perspective.

The First and Second Symposia presented solutions to a few problems confronting lagoons and identified other areas for study. However, no study has appeared and no solutions have been implemented. There are primarily three reasons for this situation:

1. Judgment by practicing engineers that present design and operation of lagoons are adequate to meet water quality criteria

2. Inability of researchers to effectively communicate their findings in a readily utilizable format

3. Lack of leadership at the state and federal levels

The prevailing attitude of the Second International Symposium is represented in the summary paper delivered by Vennes (30). Summarizing the state-of-the-art of facultative lagoons, Vennes reported that it is axiomatic that goals of waste treatment are concerned with two processes:

1. Removal (or great reduction) of infectious agents, and

2. Transforming utilizable inorganic and organic substrate into stable end products

The efficiency with which this is accomplished, Vennes reported, relates primarily to the aerobic status of the upper layers of the pond; therefore, primary consideration must be given to optimizing algal growth.

It may be inferred from these comments that facultative design has been directed toward optimization of algae production for two reasons:

1. To provide a source of oxygen to maintain aerobic conditions in lagoons, and

2. To transform utilizable inorganic and organic substrate into algae cellular matter.

The error in this logic is evident. First, algae, although a more stable organic than feces, still exerts its ultimate BOD when discharged into receiving waters. Second, and probably more important, the premise that the goal of waste treatment is to transform utilizable inorganic and organic substrate into algae is wrong. The only goal of waste treatment that will lead to the restoration and maintenance of receiving water quality is this: Pollutants must be removed from waste streams prior to discharge into the receiving stream.

Vennes (29) further documented the Symposium's mood by reporting the work of Neel, et al. (30), who presented results which would seem to indicate the relationship of stabilization lagoon effluents to water criteria.

The resulting reduction of effluents reported in the study by Neel, et al. are shown in Table 6. With an algae concentration in the lagoon effluent of 1.4×10^7 counts/100 ml. It is inconceivable that lagoons could improve receiving water quality or that these lagoons could be considered equivalent secondary treatment.

MOOD OF EPA FEDERAL PARTICIPANTS AT THE SYMPOSIUM

The mood of the Second International Symposium was best typified by the comments of Thieme (31), Middleton and Bunch (32), Williamson (33), and Alum and Carl (35). The key note address by Thieme (31) indicated that since the 1940's, increased per capita consumption of water and other resources has greatly increased water pollution. The only answer to this growing problem is to increasingly provide more efficient treatment systems which will eventually lead to recycling and reuse of treated wastes.

TABLE 6

EFFLUENT REDUCTIONS

	Raw Sewage	Effluent	Reductions
	mg/l or MPN/100		(percent)
BOD_5	267	29.4(10.7)*	89(96)
Organic P	12.2	2.7(1.0)	78(92)
PO_4	25.2	5.5(2.3)	78(91)
Organic N	131.7	6.6(2.6)	95(98)
Ammonia N	30.1	5.4(2.1)	82(93)
Coliform	3.7×10^7	1.4×10^2(3.7)	99.9996(99.9999)
Algae	nil	1.4×10^7	---

*Numbers in ( ) represent filtered valves.

Lagoons were neither praised nor criticized by Middleton and Bunch (32), who issued a challenge to lagoon technology. In view of more stringent water quality and aesthetic standards and enforcement, what is the future of lagoons in waste treatment? Can lagoon effluent quality be predetermined in the planning and design stage? Do lagoons consistently produce high effluent quality the year-round? Can lagoons be modified and operated to meet future water quality standards on a sustained basis?

MOOD OF KEY STATE ENGINEERS

Williamson (33), in welcoming the symposium participants, and Alum and Carl (34), in reporting the role of lagoons in waste treatment, indicated that in the years since 1940, lagoons have been applied to a wide variety of domestic wastewater treatment problems and are today considered a permanent form of waste treatment. About 28 percent of all waste treatment facilities are classified as lagoons and, generally, there has been universal acceptance of this method of treatment.

Alum and Carl (34) further reported on a 282-acre lagoon complex serving about 14,000 people which provides 100 percent treatment for 362 days per year. The last two ponds in two parallel series of facultative ponds are drawn down for two or three days in early fall to permit complete retention through the late fall, winter, spring, and summer. Although performance studies were not conducted in the largest South Dakota installation, fecal coliform counts of consistently less than 20 per 100 ml and occasionally even zero in the last ponds of each series led Alum and Carl to believe a satisfactory level of treatment was being obtained, especially since there was no effluent from the system except for two or three days a year.

There appears to be no maximum limit to the size of a community that can be served by lagoons, except as economically constrained by land costs. While there are finite limits to the size of any one lagoon, the largest of cities could use lagoons with split flows and parallel operation. Lagoons are still the most economical treatment facilities and might even be considered a good investment.

Simplicity of operation has been and continues to be one of the outstanding attractions of the lagoon method of treatment. Maintenance of dikes to preserve the water-holding capacity of lagoons is probably the only absolutely necessary operational item in addition to seasonal draw-downs in colder regions to permit complete holding during winter months. Certain routine care of lagoons in South Dakota was insured, but they continued to function well with or without much attention. Alum and Carl concluded that a deliberate effort is almost needed to prevent properly loaded ponds from functioning satisfactorily (34).

This attitude was further substantiated by a survey of municipal officials (34) which reported that, although lagoons receive little or no operation attention, the arrangement is "satisfactory". Alum and Carl reported that this substantiates the necessity for simplicity of lagoon operations.

Following this broad endorsement of lagoons, Van Heuvelen (35) reported the results of a survey of ten Missouri River Basin states to which he directed an extensive questionnaire. The results are best summarized by the following:

"The last two decades have seen the development of waste stabilization lagoons as a sole and permanent method of wastewater treatment....Stabilization ponds provided the lowest cost for waste treatment,... good operation (sometimes 100 percent) and low expenses for operation of maintenance. We have been very satisfied with this method of waste treatment and will continue to promote this type of facility in the future....Objections have been minimal and effluent quality has been satisfactory. During this period 60 percent of the new or enlarged wastewater treatment facilities have been waste stabilization ponds" (35).

MOOD OF THE RESEARCHERS PRESENTING PAPERS

The research papers presented at the Second International Symposium can be broadly categorized as shown in Table 7. Nineteen papers on lagoon operation and performance data for facultative, aerated, anaerobic and tertiary

TABLE 7

SUBJECT OF PAPERS PRESENTED AT SECOND INTERNATIONAL SYMPOSIUM

Main Topic of Research Contributor	Number of Papers Per Topic	General Thrust or Mood of the Work Reported
LAGOON PERFORMANCE	19	Only about 6 papers reported lagoon performance data at the Symposium. Very little data of questionable validity was was collected in any of the states. Lagoons in Utah appeared to be producing high quality effluent whereas in Missouri and California, specific lagoon studies documented extremely poor effluent quality. Algae in effluents was generally considered an asset however most filtered algae before reporting effluent BOD's. Applicable data is presented and discussed in Chapter IV of this report. Qualitative discussion with little or no supportive data expressed confidence in lagoons to provide adequate secondary treatment.
Facultative	6	
Aerated	3	
Anaerobic	6	
Tertiary	1	
Die-off and Chlorination	3	
LAGOON TECHNOLOGY	17	Papers were all in support of continued use of lagoons. Generally, efforts made were to develop a rational design process and to present supportive data. There was significant recognition of the discrepancy between design and operation and performance. Some information presented could improve lagoon performance if implemented. But there was absolutely no criteria that indicated technological advances made in the last 10 years were understood, entering state design criteria, or that states were even aware of this information.
Facultative	6	
Aerated	5	
Anaerobic	6	
LAGOON IMPACT ON RECEIVING WATER	5	Without exception, all investigators reported that lagoon effluents studied significantly deteriorated receiving water quality. Two authors discussed effluent spreading and agricultural irrigation uses as alternates to direct discharge to receiving streams.

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lagoons were discussed or presented. Only six papers reported performance data at the Symposium. Qualitative discussion with little or no supportive data was used by paper authors as a basis for expressing confidence in the ability of lagoons to provide adequate secondary treatment. Algae-laden lagoon effluents were generally considered an asset or even essential to optimum lagoon performance; however, most investigators filtered algae before reporting effluent quality. Applicable data is presented and discussed in Section VI of this report.

Seventeen papers discussed the state of lagoon technology. In this category were papers whose main thrust was reporting current or refined design concepts for facultative, aerated or anaerobic lagoons; these papers supported continued use of lagoons.

The general approach developed was a rational design process based on supportive data. There was no significant recognition of the discrepancy between lagoon design, operation, and performance. It is evident that some information presented could improve lagoon performance if implemented by the practicing profession. However, there was no evidence that technological advances of the past 10 years were entering state design criteria or even being understood by the practicing profession that current lagoon design and operation is satisfactory to meet water quality criteria.

The question of the impact of lagoon effluents on receiving water quality was addressed in five papers. Without exception, all investigators reported that lagoon effluents studied significantly deteriorated receiving water quality. Two authors discussed spreading lagoon effluents to recharge groundwater and irrigate agricultural crops as alternatives to direct discharge to receiving streams. Generally these investigators expressed the judgment that lagoons as presently designed and operated could not contribute positively to the restoration and maintenance of receiving water quality.

SECTION VI

THE ADEQUACY OF LAGOONS AS EQUIVALENT SECONDARY TREATMENT

The Contractor's review of state pollution control programs, as reported in Section IV, indicated that almost without exception, permits are granted for construction of lagoons as secondary treatment. However, other than the work of Barsom (36), lagoon performance has never been studied to determine the adequacy of lagoons to provide secondary treatment.

The purpose of this chapter is to report on the adequacy of lagoon performance by evaluating actual lagoon operating data. The Contractor collected all available data including that on lagoon influent and effluent from:

1. The 50 states and 10 Regional EPA offices,
2. University research centers, and
3. Pertinent literature

As indicated in Section IV - State Programs, most states do not know how well lagoons perform. Only three states require reporting of periodic influent data and only 28 states require monitoring and reporting of effluent data. To compound this situation, the frequency of data collection required by the states is totally inadequate to evaluate lagoon performance. In addition, considerable difference exists between the scant report requirements on lagoon performance and the actual reports submitted to a regulatory agency. Influent measurement is virtually unheard of and effluent data submitted is often "dry-labed." Data that were available to the Contractor have been incorporated into this report. The Federal EPA should examine the data requirements and develop a plan to standardize analysis and reporting techniques.

Several university research centers around the United States are conducting studies on lagoons. Most of this work is directed at developing a rational design process based on laboratory or pilot scale data. These efforts

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are often elaborate, usually with the common shortcoming of not relating to the actual lagoon performance problems of poor effluent quality, organic overload and short-circuiting. There is no significant recognition of the discrepancy between lagoon design, operation and performance.

Literature has been noticeably lacking in municipal lagoon operating data since the early 1960's. Available validated data reported in the literature through 1969 was reported by Barsom (36), and the Contractor has updated this work through January, 1972. It is evident that insufficient data have been published on lagoon performance.

DEFINITION OF WASTEWATER TREATMENT

In natural purification, energy-yielding life processes such as bacterial oxidation, combined oxygen with organic wastes $(CH_2O)_x$ produces carbon dioxide, water and energy:

$$CH_2O + O_2 \xrightarrow{\text{bacteria}} CO_2 + H_2O + \text{energy}$$

In photosynthesis carried out by algae, energy is fixed as organic matter and oxygen is liberated:

$$CO_2 + 2H_2O + \text{energy} \xrightarrow{\text{algae}} CH_2O + O_2 + H_2O$$

The elements contained in organic matter are repeatedly oxidized and synthesized, gaining energy through the combination of light and energy. This cyclic process is known as the Law of Recycle.

A lagoon is a naturally complex biological ecosystem, comprised of reducers, producers and grazers. Influent putrescible organics are degraded by bacteria which yield inorganic end products. These end products of the reducers are synthesized by the primary producers to organic matter, which is then passed up the food chain until death and recycled by reducers and primary producers. Thus, lagoons with their great surface area exposed to sunlight, and their waters rich in nutrients, serve as basins for the natural recycle of pollutants.

Oswald (37), McKinney (38), Gloyna (39), Parker (19) and others have verified this cyclic bacteria-algae symbiosis as the dominant process operative in lagoons. For this reason, many investigators (4) have considered lagoons ideal forms of waste treatment.

While lagoons more closely approach natural purification than any other treatment process, the objectives of natural purification and waste treatment are different. The goal of natural purification is to recycle pollutants. The goal of waste treatment is to remove pollutants. Oxidation ponds, emulating natural purification, recycle rather than remove pollutants. This is the fundamental reason why lagoons as presently designed and operated, are unable to achieve acceptable effluent quality and should not be considered equivalent to secondary treatment processes which do provide a positive mechanism for the removal of water pollutants.

DEFINITIONS OF SECONDARY TREATMENT

The keystone of America's clean water program is the 1965 Water Quality Act (40), which called for all states to establish water quality standards for their interstate and coastal waters; and required states to make crucial decisions concerning the uses of their water resources, the quality of water to support these uses, and specific plans for achieving such levels of quality. As reported in Section IV - State Programs, few states have moved to achieve these goals in a rational manner. Although most states have agreed to provide secondary treatment of all municipal wastewater by 1975, two things are painfully clear:

1. NEITHER THE STATES NOR THE FEDERAL EPA HAVE SET FORTH A QUANTITATIVE DEFINITION OF SECONDARY TREATMENT;

2. NO AGENCY KNOWS IF SECONDARY TREATMENT WILL PROTECT THE DESIGNATED LEGITIMATE USES OF RECEIVING STREAMS.

Although wastewater treatment systems are frequently designated as primary or secondary, there is little agreement on what actually comprises secondary treatment. The Contractor found this a genuine stumbling block in performing this contract since one condition to be studied was the adequacy of lagoons to provide secondary treatment, and to compare lagoon performance with secondary treatment process performance.

Primary treatment is the process of physically removing pollutants from wastewater, usually by sedimentation, but removing little or no colloidal and dissolved matter from the water. BOD reduction of about 30 percent is achieved, and about 60 percent suspended solids are removed. In many places and in the past, primary treatment was the only treatment wastewater received.

Secondary treatment has traditionally been thought of as biological treatment of wastewater: bacteria and microorganisms break down complex organic pollutants to more stable substances (41). These processes can remove 99.9 percent of the 5-day BOD if the biological process is followed by separation of the stable organic material (sludge formed).

Advanced waste treatment has developed as a group name for various chemical, physical, or biological processes used to remove the residues after secondary treatment. Processes such as microstraining, chemical precipitation of phosphate and anaerobic denitrification of a wastewater stream are examples of advanced waste treatment.

At times, the lagoon has been called on to provide these types of treatment either alone or in combination with other unit operations which may themselves be lagoons. Being a basically uncontrolled process, the lagoon has had trouble doing all of this.

Historically, wastewater treatment has been divided into primary and secondary treatment, and lagoons have been considered secondary treatment. But the question arises, "What is secondary treatment?". Environmental engineers use secondary treatment to mean removal of dissolved organic materials, as well as most suspended solid material, but there is no standard definition of the process or precise statement of its goals. Because of this lack of clear definition, what one state calls secondary treatment may not be adequate in another.

The Contractor investigated several sources of possible definitions to provide a working base in evaluating the performance of lagoons.

The most specific and comprehensive definition was given at 1970 symposium by Middleton and Bunch (32):

> "For our discussion we will adopt the following liberal definition of secondary treatment. Secondary treatment is any treatment given wastewater that will produce an effluent containing less than 30, 75, 25 mg/l of BOD_5, COD, and suspended solids, respectively. These values shall not be exceeded more than 10 percent of the time on daily composite samples taken proportional to flow. The effluent produced shall be nontoxic and free of offensive color and odor. In addition, the effluent must meet the bacteriological quality standards promulgated by the various states."

This definition is not official FWQA/EPA policy. It does, however, provide a goal for producing effluent of sufficiently high quality so as not to damage most streams.

Currently, the closest semblance of a Federal definition of secondary treatment appeared in the Federal Register, setting forth conditions to be met if Federal construction grant money is used to finanace a treatment system:

1. Substantially complete removal of all floatable and settleable materials;

2. Removal of not less than 85 percent of 5-day biochemical oxygen demand;

3. Substantially complete reduction of pathogenic microorganisms; and

4. Such additional treatment as may be necessary to meet applicable water quality standards.

These criteria demand very little since the solids removal is based on floatable and settleable rather than suspended solids. The BOD removal of 85 percent is not difficult to achieve, but the data available on lagoon operation presented in this section, will seldom be sufficient to judge whether that requirement is being met. The data are usually grab samples taken at sporadic and very infrequent intervals.

Other definitions of secondary treatment were collected from several states and are given below:

NEBRASKA: (42)

> Secondary Treatment - A method of waste treatment beyond primary treatment where pollutants in solution or the colloidal state are biologically or chemically removed. The minimum treatment required under this method is removal of at least 85 percent of the BOD and suspended solids.

MISSOURI: (43)

> In providing for the enhancement of water quality, consistent with reasonable, feasible, and achievable waste treatment, the Board will require secondary treatment of all municipal wastes and the equivalent of secondary treatment of all industrial waste. The equivalent of secondary treatment for industrial waste may be accomplished by control and/or process change.

KANSAS: (44)

> All municipal wastes discharged within the Upper Republican River basin shall receive a minimum of secondary treatment to achieve a minimum of 85 percent reduction of the five-day biochemical oxygen demand by December 31, 1975. All industrial wastes discharged within the Upper Republican River basin will receive an equivalent treatment by December 31, 1975. The objective of treatment or control will be to reduce the organic load, oil, grease, solids, alkali, acids, toxic materials, color and turbidity, taste and odor products and other deleterious materials to the lowest practicable level.

Continuous disinfection of treated wastes shall be provided for those municipalities and industries which contribute bacterial loadings to a river or stream used as a downstream public water supply and which supplies are within the zone of bacterial influence.

IOWA: (45)

Treatment: All municipal wastes discharged into the interstate waters of the Mississippi River and the Missouri River shall receive a minimum of ninety percent (90) reduction of BOD prior to discharge, no later than dates fixed by order of the Iowa Water Pollution Control Commission. All industrial wastes discharged into such interstate waters shall receive equivalent treatment prior to discharge, no later than dates fixed by order of the Iowa Water Pollution Control Commission.

ALABAMA: (40)

The term "secondary treatment" as applied to sewage is interpreted to mean a process or group of processes capable of removing virtually all floating and settleable solids, from 75 to 95 percent of the 5-day biochemical oxygen demand and in excess of 75 percent of suspended solids contained in untreated sewage.

IDAHO: (47)

For the purposes of these regulations, minimum adequate treatment for domestic sewage or industrial wastes containing significant organic material shall be equal to that which is commonly known as secondary treatment or the equivalent of 85 percent removal of the biochemical oxygen demand including adequate disinfection of any wastes which may contain organisms that may produce disease in man or animals. In industrial processes, in-plant process controls or alterations, carried out for the primary purpose of waste reduction, shall be considered as a part of the treatment process. Exceptions to secondary treatment requirements may be made by the Department of Health

> when it can be demonstrated that such exceptions will not adversely affect classified water quality and will offer adequate protection for all beneficial uses. Failure to provide adequate treatment shall be considered a violation of these regulations.

From all these definitions, one constant factor filters through: approximately 85 percent BOD reduction as the waste is processed. This figure may be fine, but it implies measurements; measurements of influent and effluent are needed to calculate a reduction in waste strength. Unfortunately, few places regularly measure influent and effluent concentrations so it is impossible to know what reduction is occurring. And, if the treatment requirement is based on a percent reduction, it is unknown if the treatment facility is meeting its requirements. To alleviate this problem, a number of states define lagoons as providing secondary treatment, thereby minimizing the need to measure lagoon performance.

LAGOON PERFORMANCE

As indicated in Section III, lagoon classification is rather vague and general, and considerable overlap exists when lagoon types are discussed. Care should be exercised when evaluating the performance of lagoons on an individual basis.

For the purpose of this report, lagoons have been classified as:

1. Facultative (Oxidation) Lagoon

- Photosynthetic oxygenation and surface reaeration are the main source of oxygen.

- Mechanical equipment is not a part of a conventional facultative lagoon.

- Oxygen stratification with an aerobic and anaerobic lagoon.

- Average detention time of 40 days.

- Organic loadings of 10 to 100 lb. BOD_5/acre/day.

- Usually 3 to 5 feet deep.

2. Aerated Facultative Lagoon

- Main source of oxygen is from mechanical aeration and some photosynthesis.

- Aerobic, anaerobic stratification may or may not occur depending upon the level of mechanical mixing.

- Average detention time ranges from 1 to 2 days to 30 days.

- Organic loadings of 10 to 300 lb. BOD/acre/day.

3. Oxidation Ditch

- Main source of oxygen - mechanical brush aerators.

- Shaped like a race track.

- Organic loadings of 25 to 200 lb. BOD/acre/day.

- Average detention time 24 hours a day.

- Oxidation ditch effluent passes through a clarifier for solids separation.

- Depth usually 5 to 10 feet.

4. Tertiary Lagoon

- Usually does not receive mechanical aeration.

- May or may not be stratified.

- Detention time of a few hours to a few days.

- Receives a secondary effluent.

- Organic loading of 12 to 50 lb. BOD/acre/day.

- Depth range from 1 to 5 feet.

The Contractor team evaluated lagoon performance for all 50 states and approximately 3000 lagoon installations. Data of even marginal validity was available from less than 200 lagoon installations. These data are presented as the basis of the Contractor's evaluation of lagoon performance as equivalent secondary treatment.

As discussed in Section IV, State Programs, little or no lagoon effluent data are collected in the 50 states of such frequency to present a definitive picture of lagoon performance. The great volume of poor quality data has necessitated a statistical approach by the Contractor to this section. This approach was as follows:

1. Calculation of the range and median value for lagoon effluent quality by state.

2. Grouping lagoon effluent data by geographic region as presented in Chapter II.

3. Plotting the range in effluent quality of a particular parameter by geographic region.

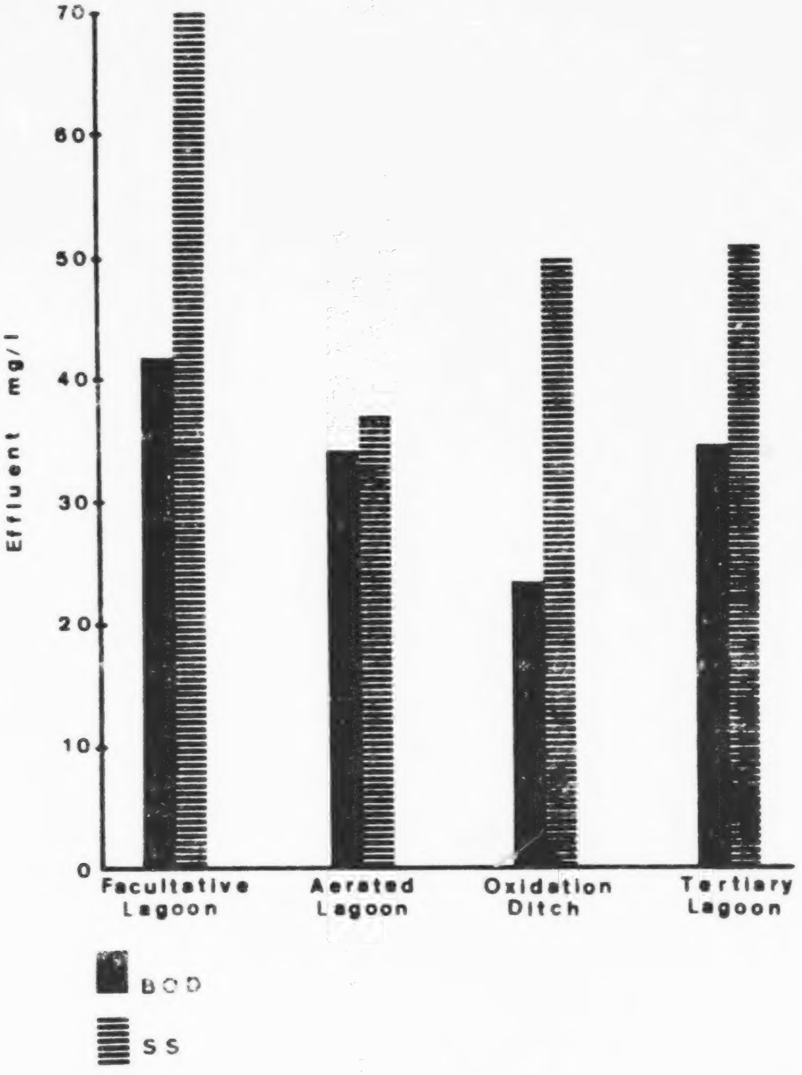
4. Plotting the average of the states median effluent values by geographic region.

The overall performance of the four major types of lagoon systems is shown in Figure 3. The average median effluent five-day Biochemical Oxygen Demand (BOD) and effluent Suspended Solids (SS) for facultative aerated and tertiary lagoons is shown with the average median effluent values from oxidation ditches. The average median effluent BOD ranged from 23 mg/l to 42 mg/l and the average median effluent SS ranged from 37 mg/l to 67 mg/l. These values exceed accepted standards for secondary treatment.

The figure clearly shows that neither BOD nor suspended solids is at an acceptably low level. Data from many sources are measured in different ways making it difficult to be conclusive but the high suspended solids in the facultative and tertiary lagoons are probably due to algae cells. Based upon available data, aerated lagoons which do not depend on algae have a much lower solids level although they are still not acceptable as secondary treatment.

FIGURE 3

AVERAGE MEDIAN EFFLUENT VALUES



Facultative Lagoon Performance - Figures 4 through 8 present validated effluent quality data from facultative lagoons. To aid in data presentation, effluent data from states have been grouped by geographic region and only ranges and average median values are plotted.

Facultative lagoon effluent BOD range and median values are plotted in Figure 4. Effluent BOD ranged from 10 mg/l to about 200 mg/l and the average median values ranged from 25 mg/l to 75 mg/l. Since facultative lagoon effluents are often algae laden, the five-day BOD is only about 25 percent of the ultimate BOD. Performance appears to be better in the Great Lakes and Missouri Basin, and poorest in the Southeast and Ohio Basins. No data were available from the Middle Atlantic, Northeast and Northwest regions.

Facultative lagoon effluent suspended solids (SS) data are plotted in Figure 5 by geographic region. The average median values ranged from about 40 mg/l in the Great Lakes Region to 540 mg/l in the Ohio Basin. For the remaining regions for which data were available, the average median effluent SS ranged from 80 to 110 mg/l. It is evident that these excessive effluent suspended solids greatly exceed conventional standards for secondary treatment. These solids are predominantly algae cells and when discharged to receiving waters, are capable of exerting their ultimate biochemical oxygen demand.

Facultative lagoon effluent nitrogen and phosphorus values are plotted in Figures 6 and 7. Effluent nitrogen and phosphorus values ranged between 10 and 30 mg/l and 5 and 60 mg/l respectively except in the South Central Region where the effluent nitrogen range exceeded 350 mg/l and the effluent phosphate (phosphorus reported as phosphate) range exceeded 600 mg/l. There was no apparent explanation for these atypical results. Little significance can be attached to these data which represent less than ten lagoon installations.

Figure 8 is a plot of facultative lagoon effluent chemical oxygen demand (COD). With less than ten lagoons reporting, the data are not statistically valid. These data do indicate effluent COD values ranging from 85 mg/l to 300 mg/l indicating a high amount of chemically oxidizable

FIGURE 4

FACULTATIVE LAGOONS
BIOCHEMICAL OXYGEN DEMAND

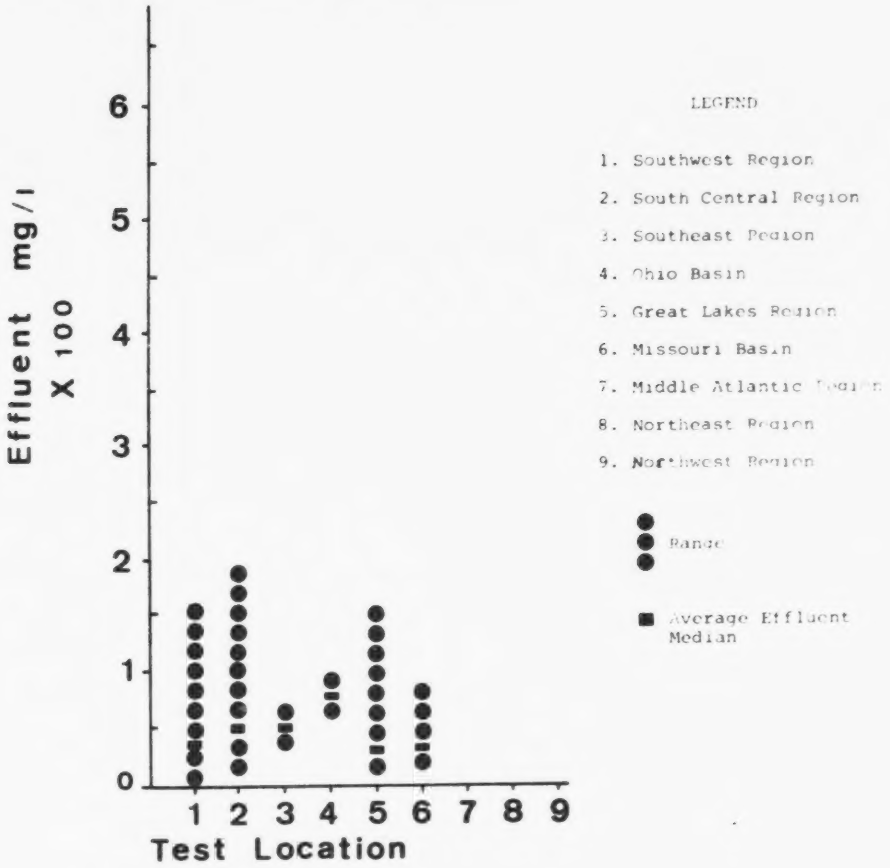


FIGURE 5

FACULTATIVE LAGOONS
SUSPENDED SOLIDS

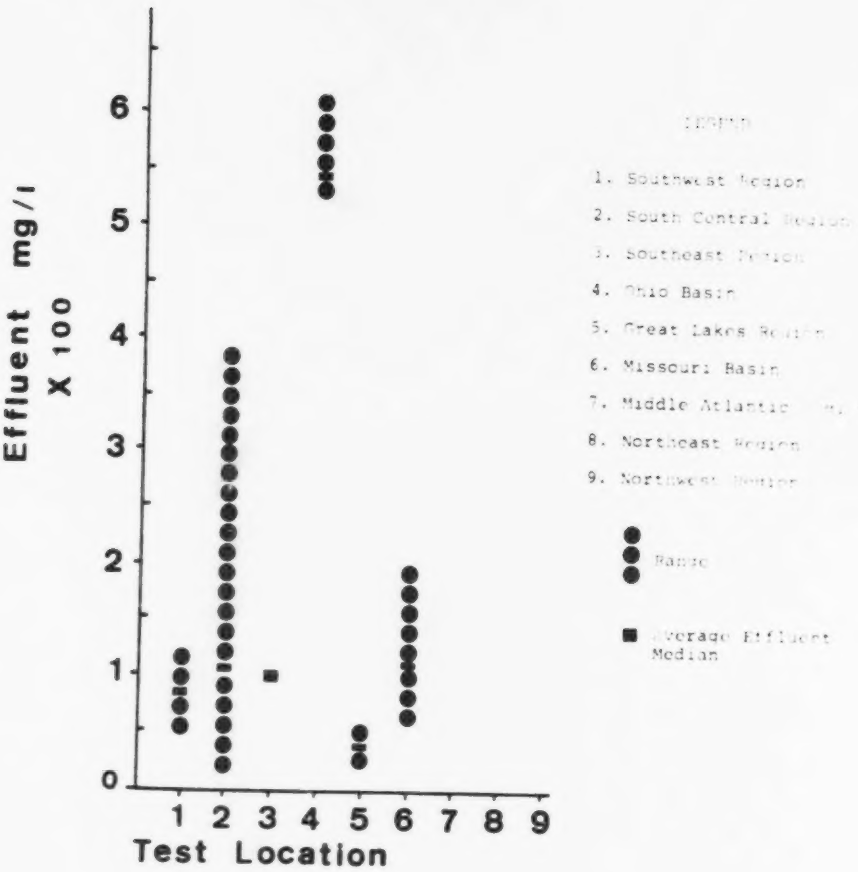


FIGURE 6

FACULTATIVE LAGOONS
NITROGEN

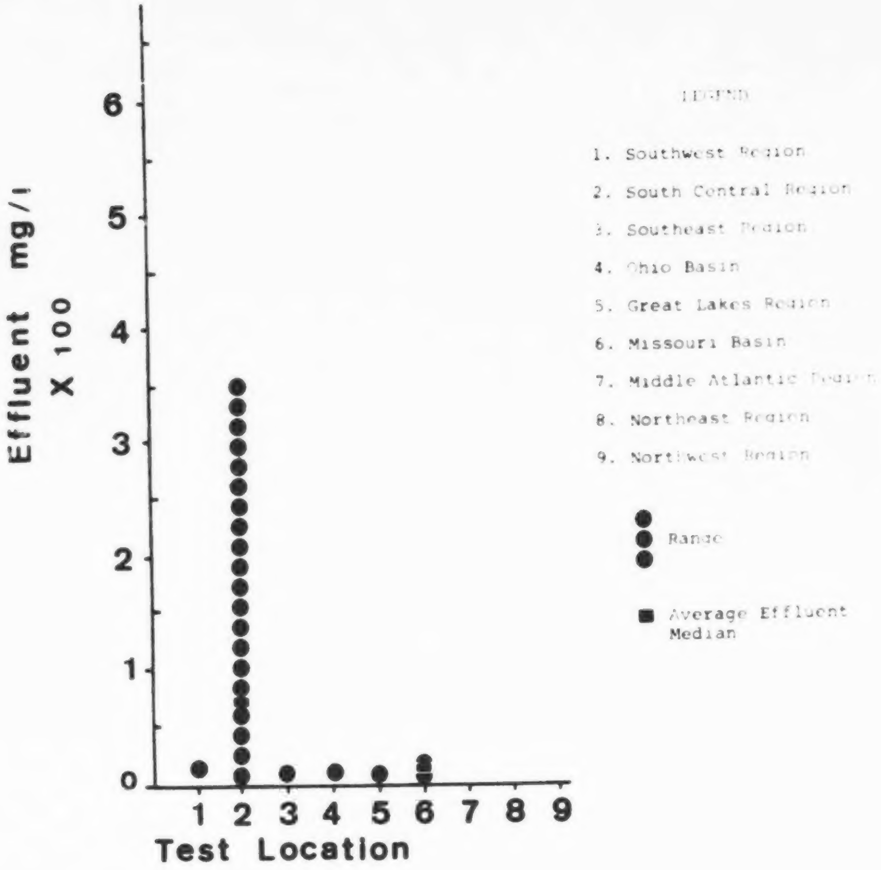


FIGURE 7

FACULTATIVE LAGOONS
PHOSPHATE

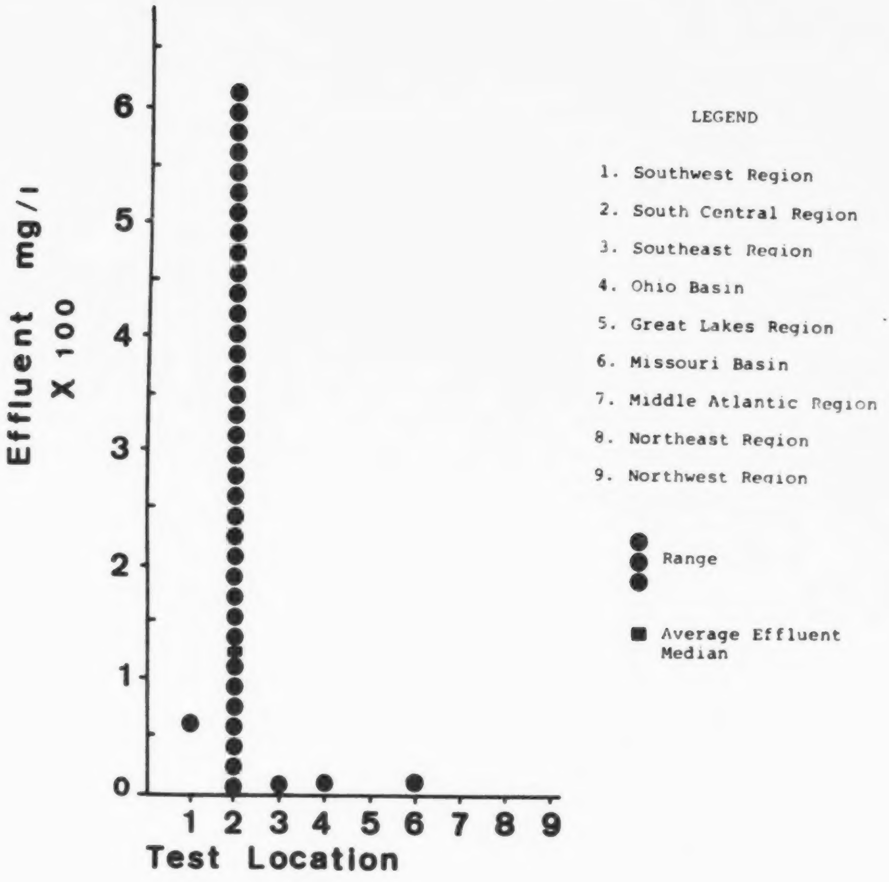
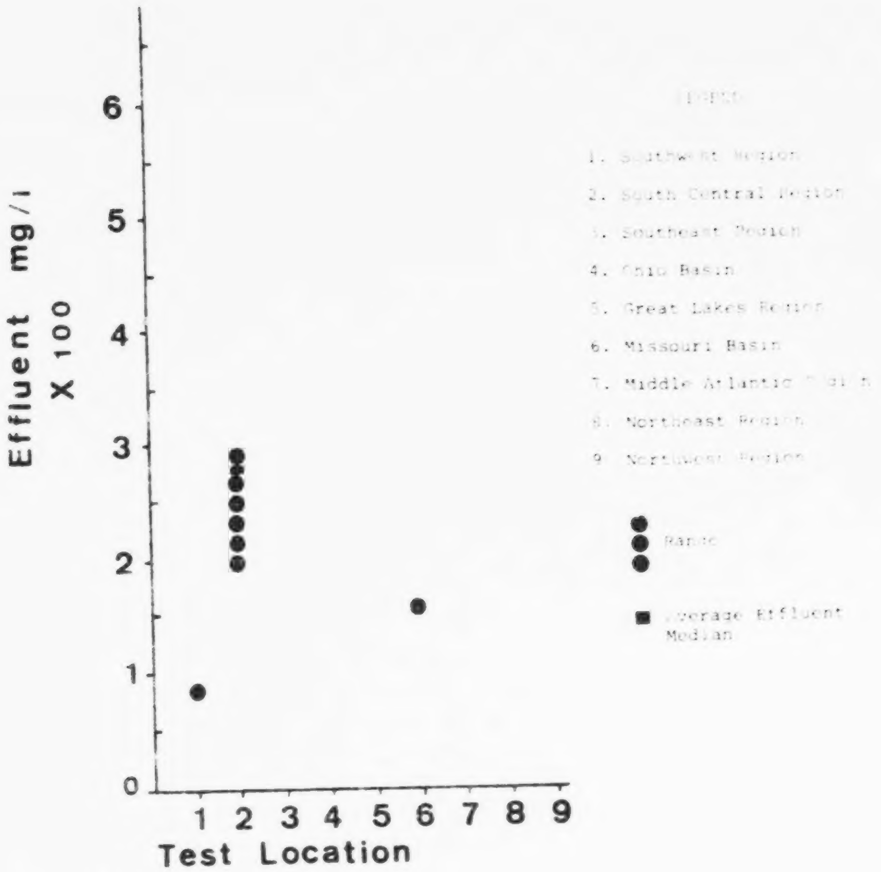


FIGURE 8

FACULTATIVE LAGOONS
CHEMICAL OXYGEN DEMAND



material in the lagoon effluents. This material was most likely algae cells.

Facultative lagoon effluent coliform counts were available only from the South Central Region and the Southeast Region. Average median coliform counts ranged from 350 counts/100 ml to about 1000 counts/100 ml, and the range in the Southeast Region exceeded 1,000,000 counts/100 ml. These widely fluctuating results point to the lack of reliability of coliform die-off in facultative lagoons.

Aerated Lagoons - BOD, SS, Nitrogen, Phosphorus and COD effluent data from aerated lagoons are reported in Figures 9 through 13. The BOD data (Figure 9) indicates the average median by geographic region ranged from 30 mg/l to 80 mg/l. These values are in excess of normal BOD values expected from secondary treatment processes. The average median effluent suspended solids from aerated lagoons (Figure 10 ranged from 60 mg/l in the Great Lakes Region to about 210 mg/l in the Northwest Region. These effluent SS were predominantly algae cells and other biological solids.

Nitrogen and phosphorus (reported as phosphate) data reported in Figure 11 and 12 was sparse and the widely fluctuating effluent values do not lend themselves to definitive conclusions.

The COD data from aerated lagoons are plotted in Figure 13. The average effluent median values ranged from 170 mg/l to 340 mg/l. These high effluent COD values are an excellent indicator of the presence of oxidizable organic matter in the effluent of aerated lagoons.

Oxidation Ditches - In recent years the extent and use of oxidation ditches has accelerated in the United States. Like lagoons, the prolification of oxidation ditches has preceeded their investigation and validation as a secondary treatment process. Although data on oxidation ditches is scarce, some data were available in 5 regions of the country. These data are plotted in Figures 14 through 17. Reported effluent BOD values generally were below 25 mg/l although in the State of Texas, the effluent BOD ranged almost 500 mg/l and the SS ranged in excess of 300 mg/l.

FIGURE 9

AERATED LAGOONS
BIOCHEMICAL OXYGEN DEMAND

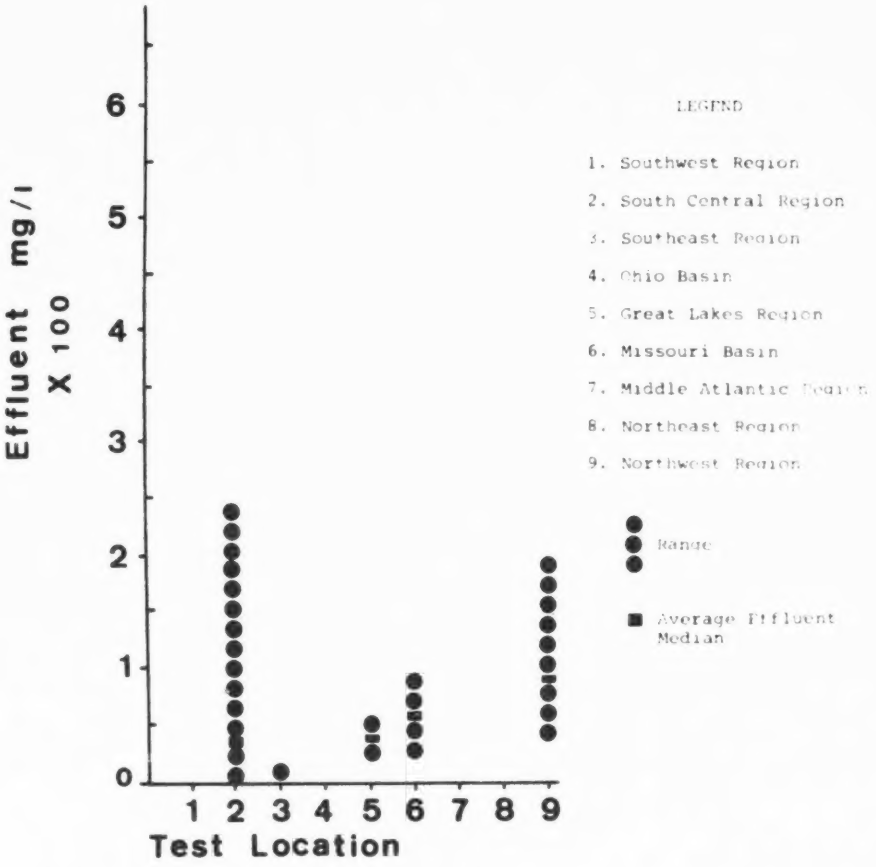


FIGURE 10

AERATED LAGOONS
SUSPENDED SOLIDS

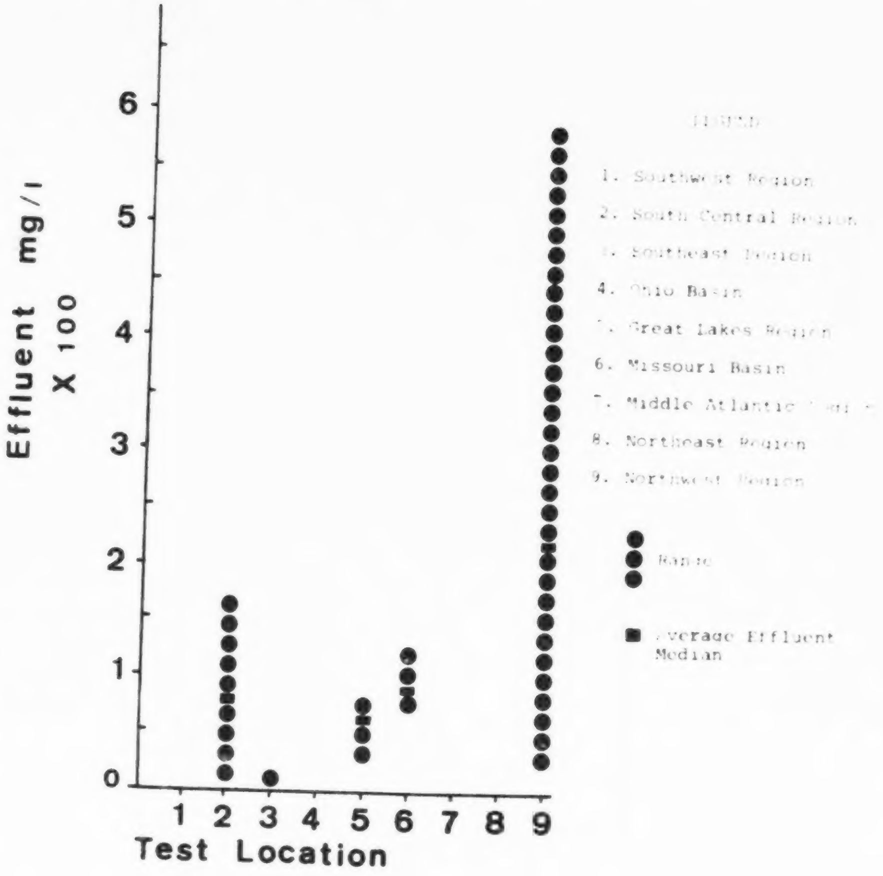


FIGURE 11

AERATED LAGOONS
NITROGEN

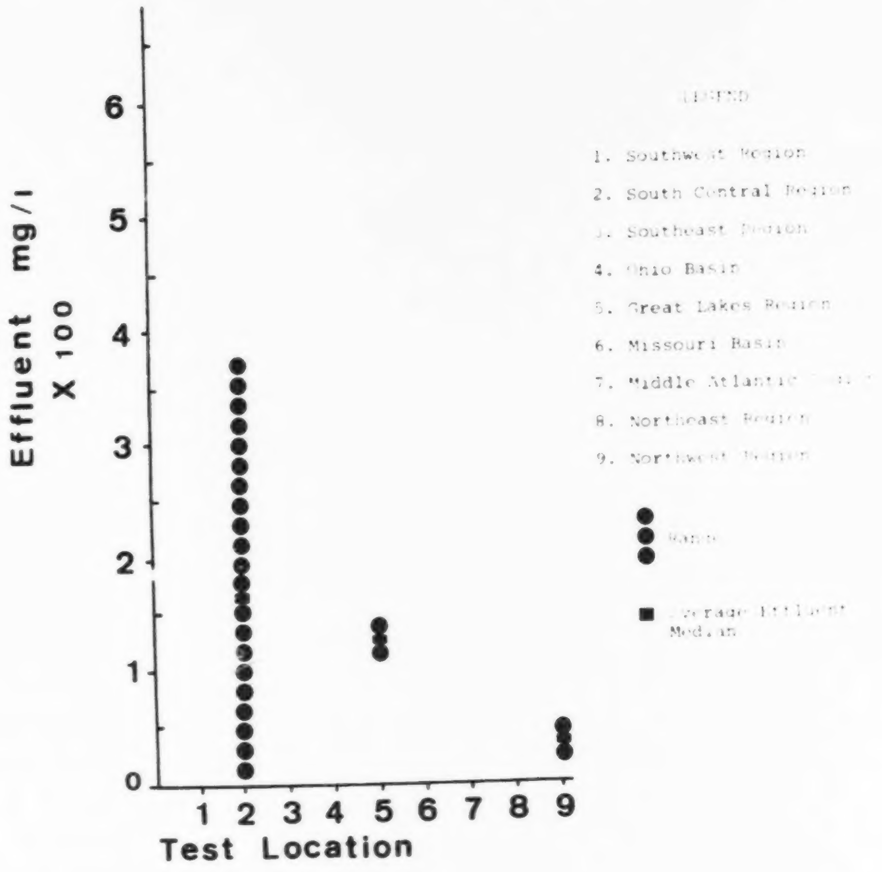


FIGURE 12

AERATED LAGOONS
PHOSPHATE

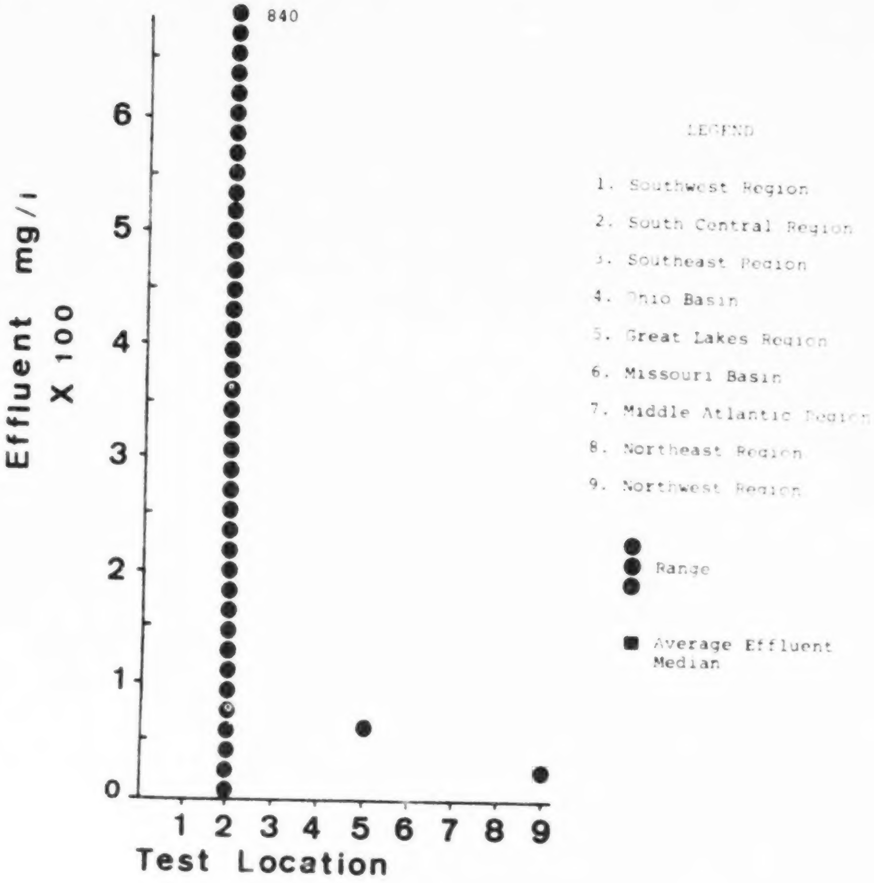


FIGURE 13

AERATED LAGOONS
CHEMICAL OXYGEN DEMAND

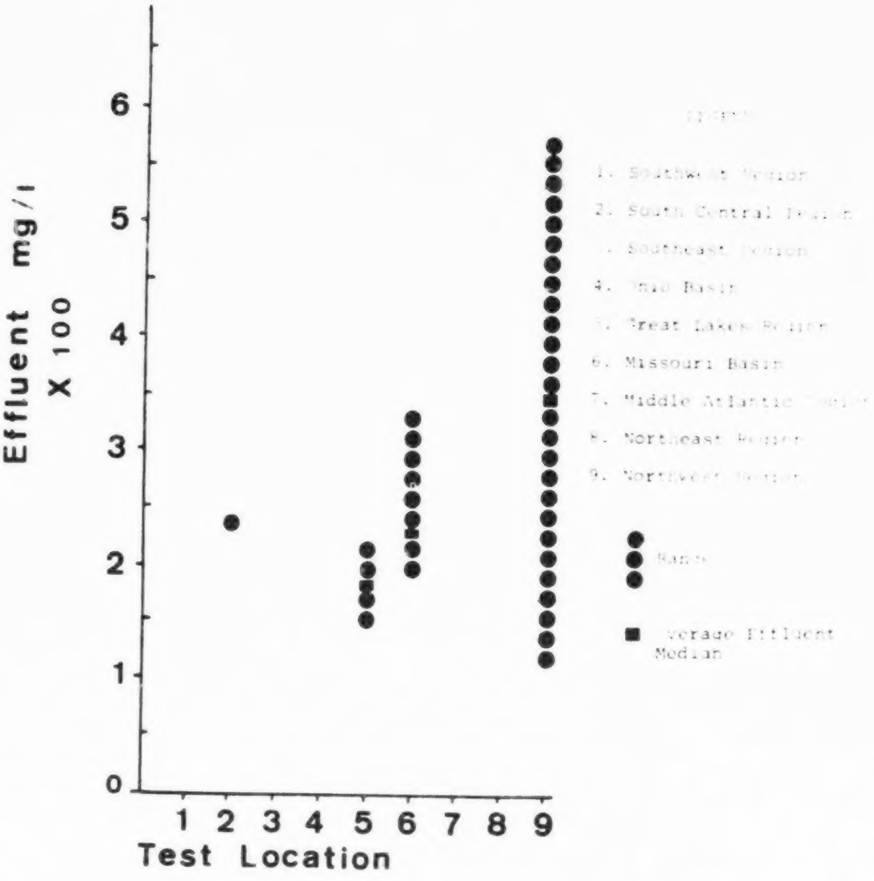


FIGURE 14

OXIDATION DITCHES
BIOCHEMICAL OXYGEN DEMAND

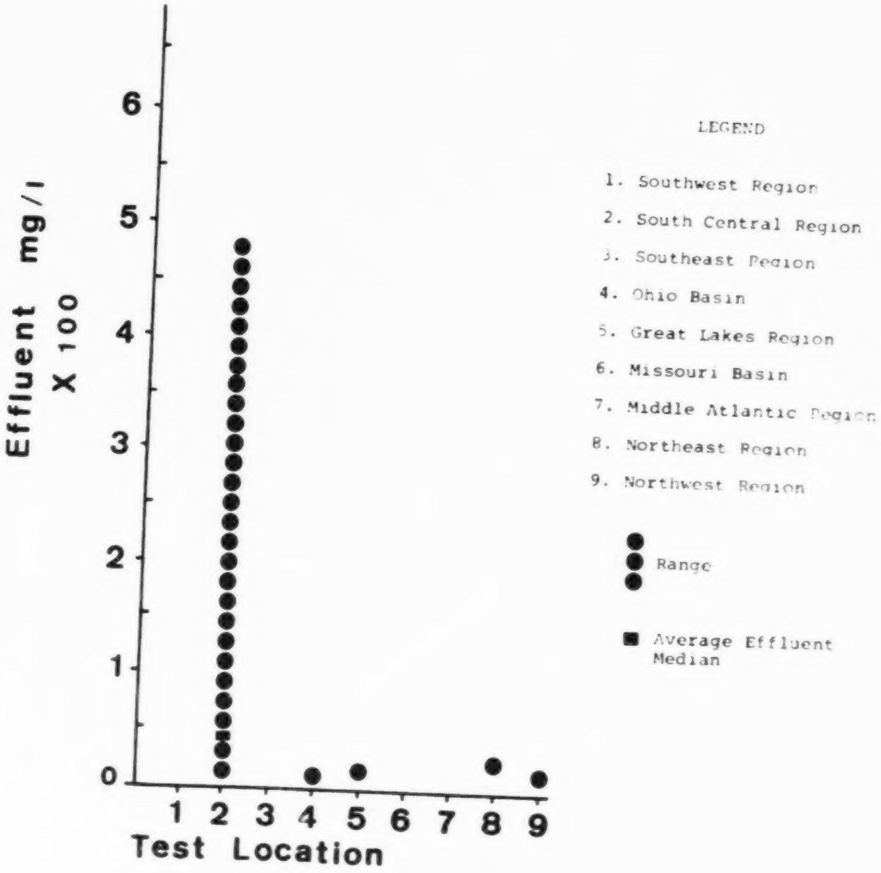


FIGURE 15

OXIDATION DITCHES
SUSPENDED SOLIDS

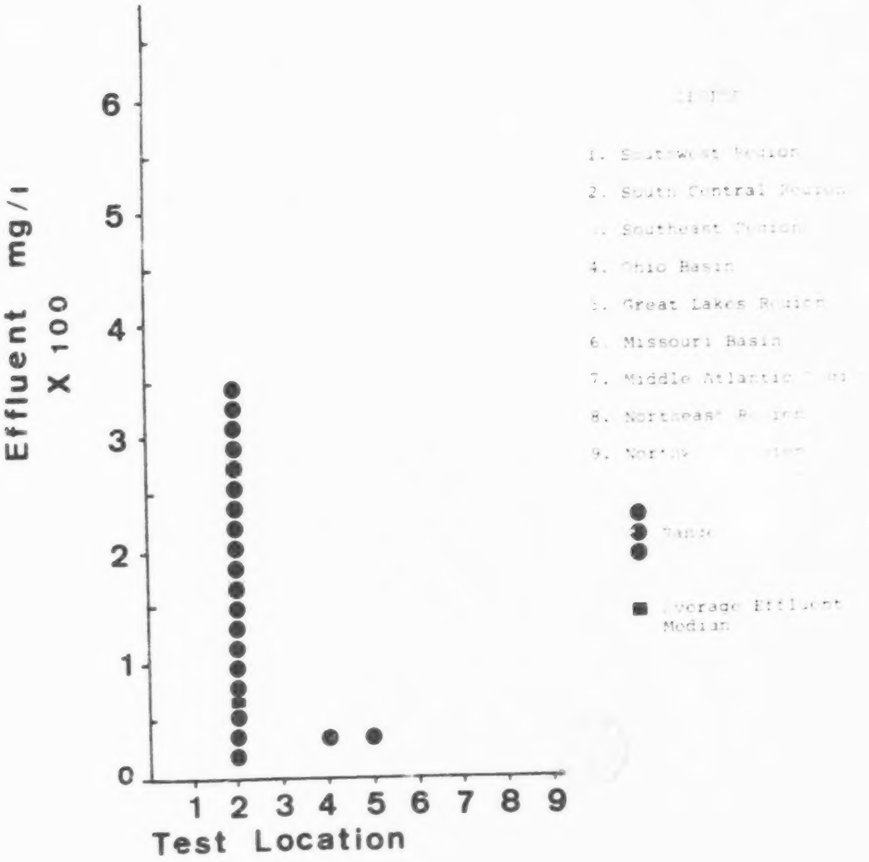


FIGURE 16

OXIDATION DITCHES
NITROGEN

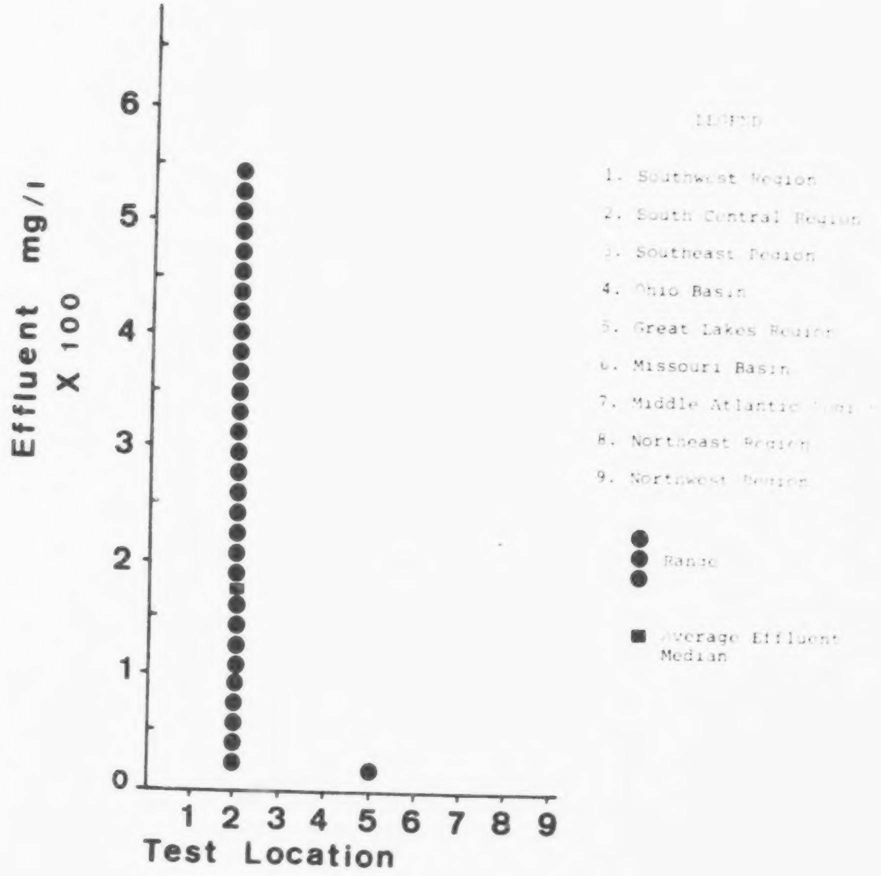
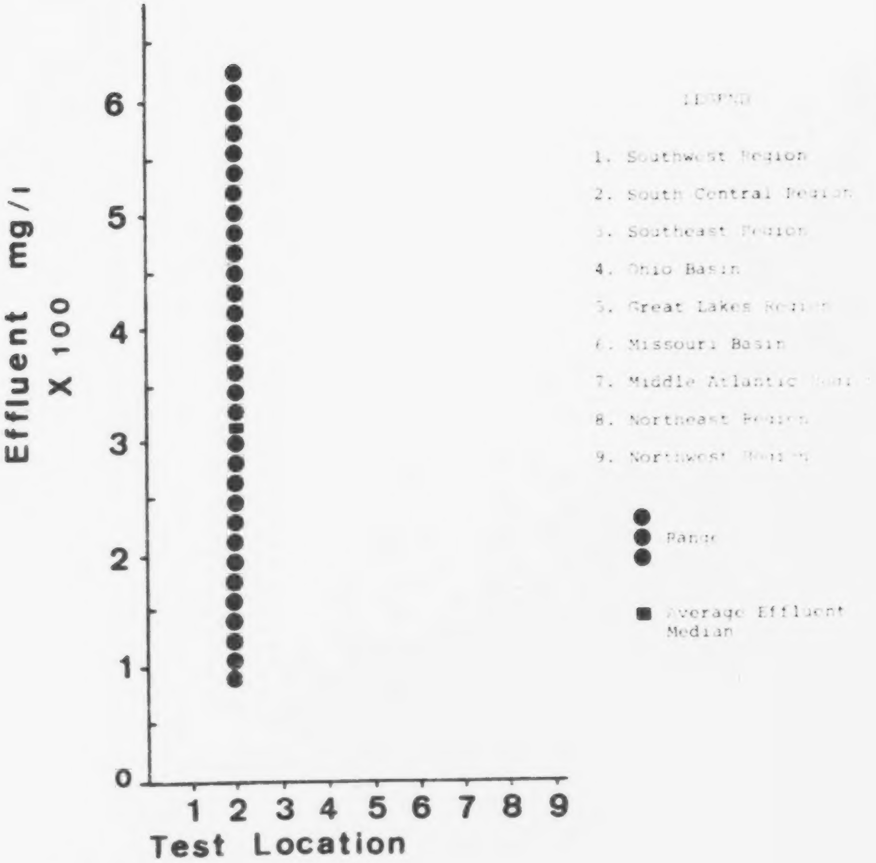


FIGURE 17

OXIDATION DITCHES
PHOSPHATE



These somewhat anomalous results point to the need for detailed study on the performance and design criteria for oxidation ditches. Effluent nitrogen and phosphorus (reported as phosphate) data from oxidation ditches was not conclusive, further supporting the need for studies of oxidation ditch performance.

Tertiary Lagoons - BOD, SS, Nitrogen, Phosphorus and COD effluent data from tertiary lagoons are presented in Figures 18 through 22. Average effluent median BOD values ranged from 10 mg/l to about 100 mg/l. Average effluent median SS values ranged from 20 mg/l to 250 mg/l. Nitrogen and phosphorus (reported as phosphate) data ranged around 20 mg/l. COD data although extremely scarce, ranged from 130 mg/l to 575 mg/l, indicating that the tertiary pond effluents contained large amounts of oxidizable organic matter.

FIGURE 18

TERTIARY OXIDATION LAGOONS
BIOCHEMICAL OXYGEN DEMAND

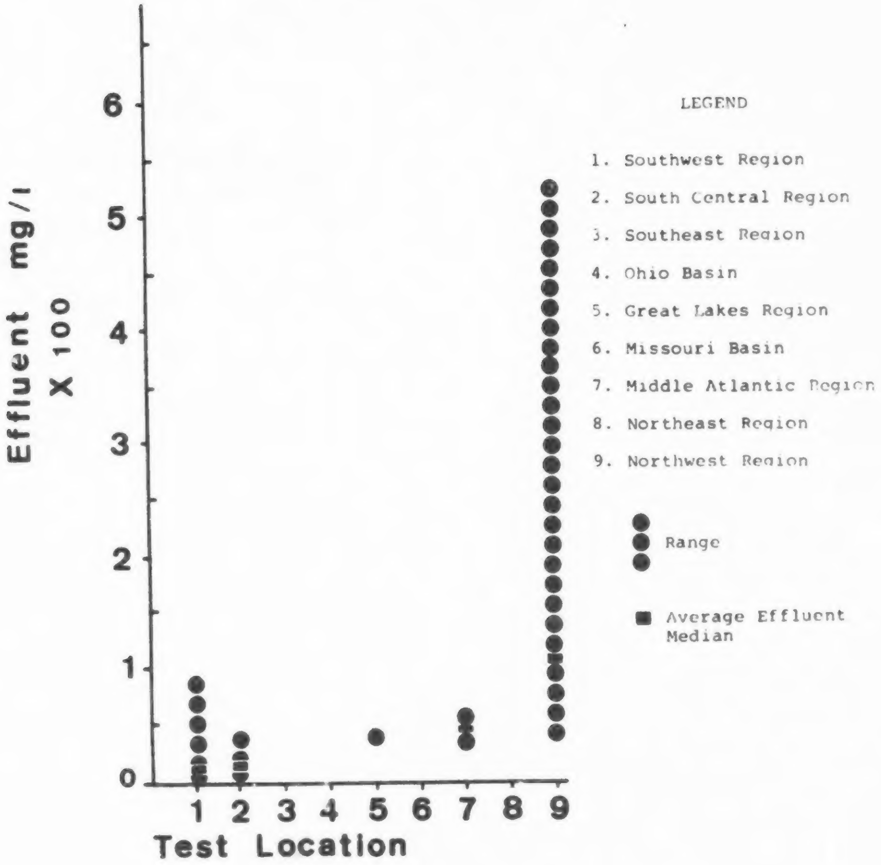


FIGURE 19

TERTIARY OXIDATION LAGOONS
SUSPENDED SOLIDS

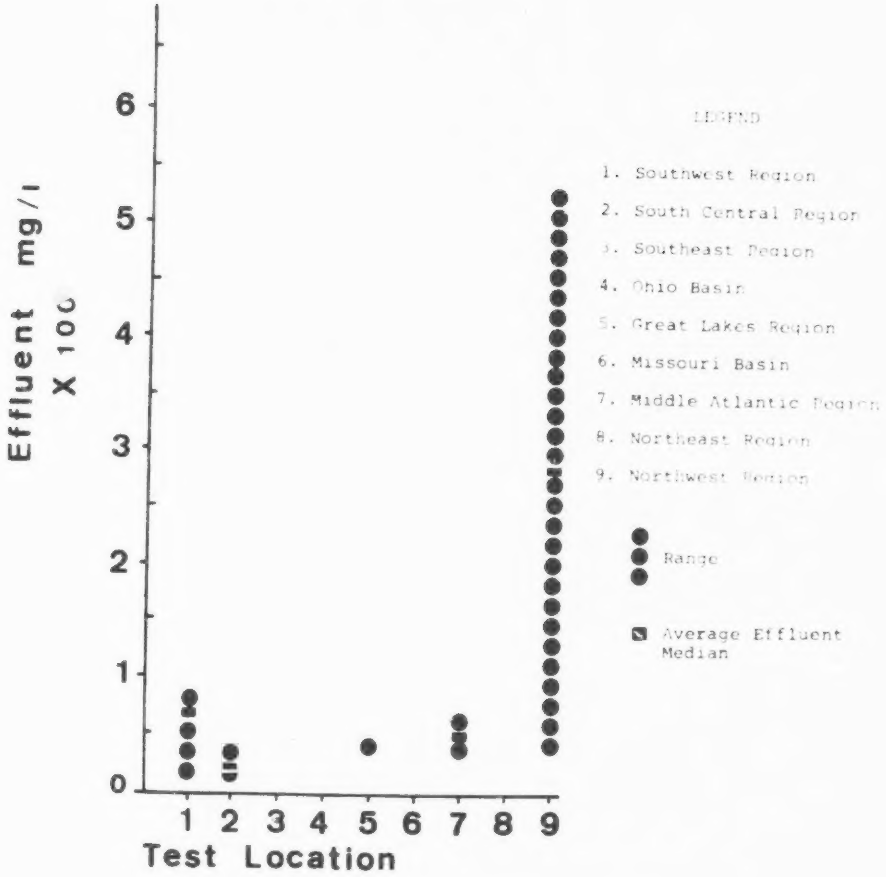


FIGURE 20

TERTIARY OXIDATION LAGOONS
NITROGEN

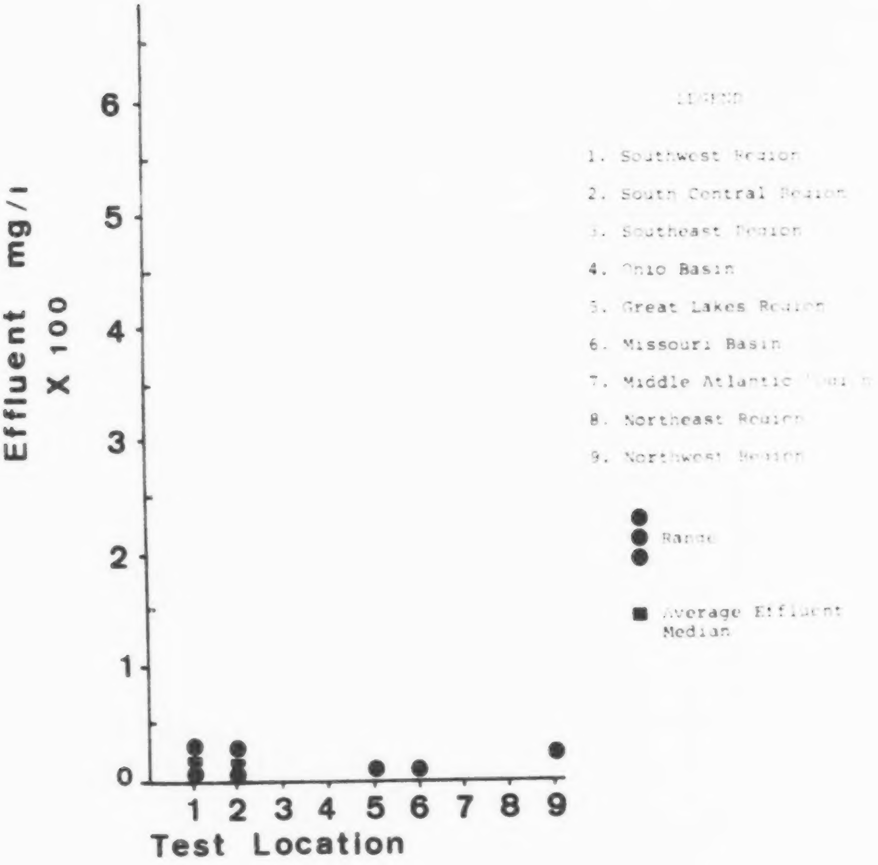


FIGURE 21

TERTIARY OXIDATION LAGOONS
PHOSPHATE

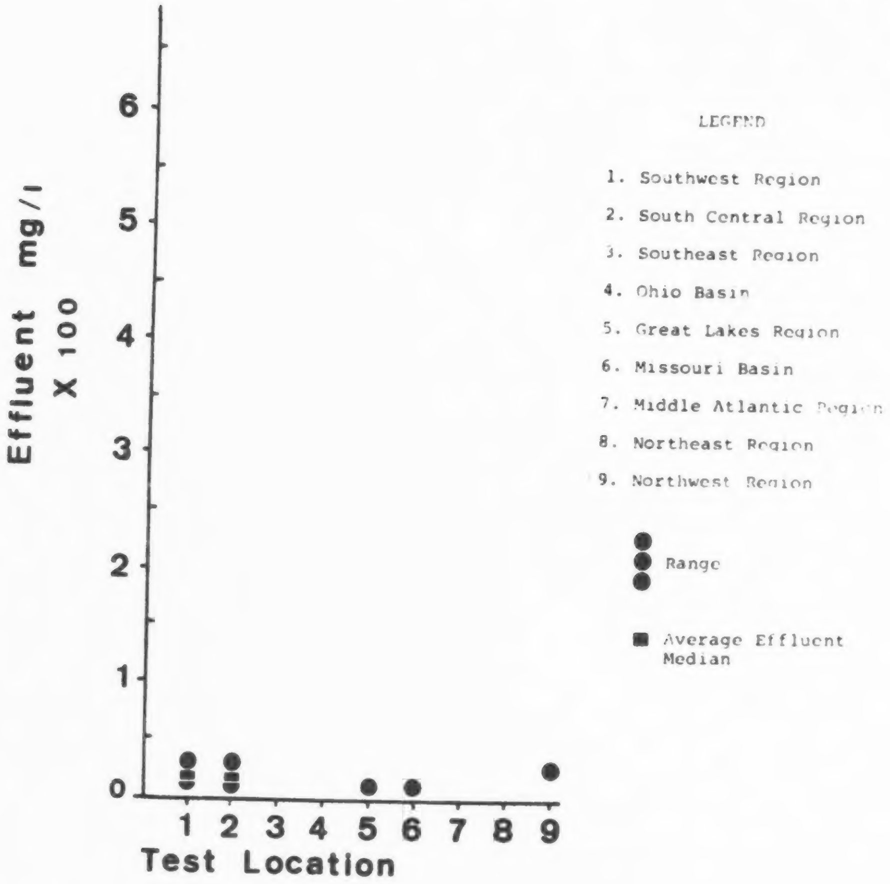
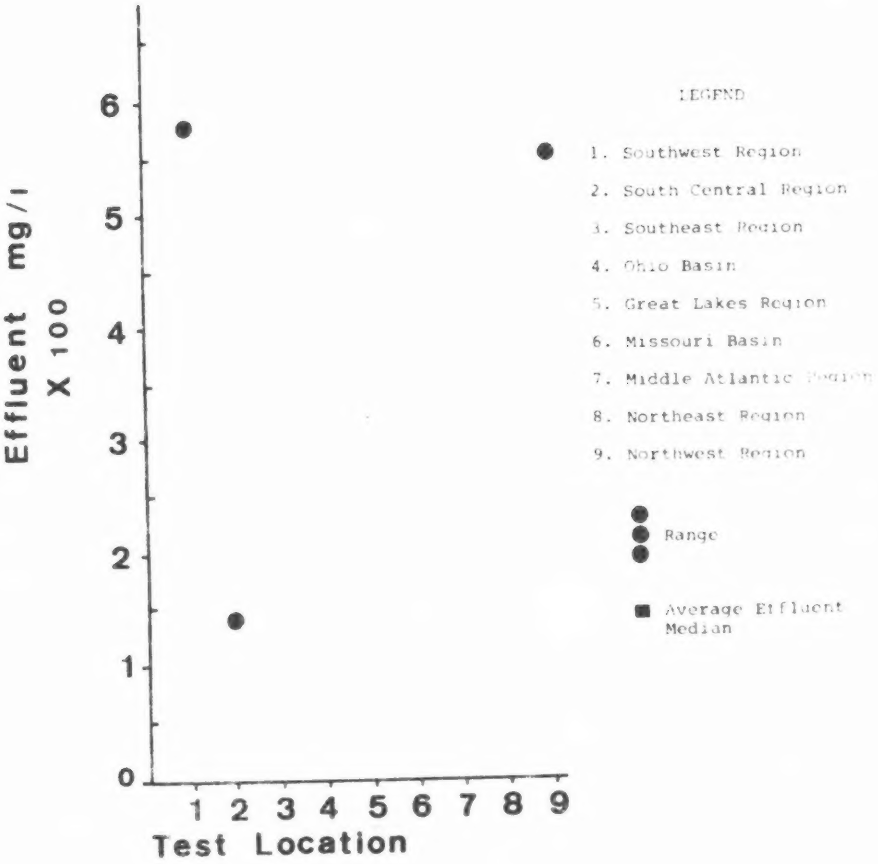


FIGURE 22

TERTIARY OXIDATION LAGOONS
CHEMICAL OXYGEN DEMAND



IMPACT OF LAGOON EFFLUENTS ON RECEIVING WATER QUALITY

The 1965 Water Quality Act (46), authorized the states and the Federal government to establish water quality standards for interstate and coastal waters by June 30, 1967. These standards of receiving water quality were to be established to protect the public health or welfare and to enhance the quality of water. In establishing such standards the appropriate state authority was to take into consideration their use and value for public water supplies; propagation of fish and wildlife; recreational purposes; and agricultural, industrial, and other legitimate use.

The standards adopted by the States were to include water

1. use classifications,

2. criteria necessary to support these uses,

3. enforcement, and

4. a plan for implementation which would include acceptable methods of treatment.

Selection of treatment methods was to be dependent upon the process' ability to produce an effluent that would meet criteria necessary to maintain established water uses and enhance receiving water quality (46).

Since the adoption of this act in 1965, state progress has been slow, lethargic and noticably lacking in imagination. States have generally classified receiving water uses; however,

1. they have not established criteria necessary to support these uses,

2. they have not adopted functional enforcement programs,

3. they have not developed systematic implementation plans, and

4. they have not defined acceptable treatment methods

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based upon the process' ability to meet specified effluent criteria necessary to maintain established water uses and enhance receiving water quality.

The impact of lagoon effluent on receiving waters is discussed in this chapter.

OVERVIEW OF THE IMPACT OF LAGOON EFFLUENTS ON RECEIVING WATER QUALITY

The question of the impact of lagoon effluents on receiving water quality really appears to be: "Does lagoon effluent degrade the quality of receiving streams?" In this section this question will be discussed in terms of environmental science principals which can be used as predictors of the impact of lagoon effluents on water quality. This discussion will lead to the presentation of specific case studies where the impact of lagoon effluents was monitored.

Many lagoons built for small or emerging community use are, by the nature of the population served, placed closer to headwaters than larger installations. In terms of immediate impact then, lagoon effluent has, or is capable of having, a more profound impact on a fundamentally higher quality stream of lesser volume - clearly a double threat to receiving water quality.

One such receiving stream reported by King (7) has been characterized as ". . . an unfortunate little stream, . ." Rather clearly, many of the streams which receive lagoon effluent are similar unfortunate little streams. By their nature, these biologically interesting and aesthetically pleasing receiving waters have periodic flow and low water levels during much of the year. They are, therefore, ill-equipped to receive any effluent.

Most states accept lagoons as providing adequate treatment to protect water quality, however, their lagoon design criteria indicate the realization by some states that lagoon effluent actually degrades receiving water quality. For example, in some states lagoon design criteria specify such volume as to allow only annual or semi-annual discharge coinciding with maximum receiving water flow. This tacit admission of the inherent failure of lagoon operation should be of sufficient magnitude to cause engineers to seek an alternative means of effluent disposal.

Further recognition of this failure is seen in many northern states in this country where combined evaporation and percolation rates are low enough to cause a heavy volume of effluent flow or where ice cover hampers lagoon performance during the winter months (48). In these states, lagoons are of sufficiently large size to allow periodic discharge.

The use of treated effluent for irrigation purposes, although an apparently satisfactory use of the wastewater, is based in part on water shortage and on the fact that the effluent produced by oxidation ponds is not always adequate to meet state water quality criteria. Land disposal of lagoon effluents should receive close evaluation as it may be a more desirable method of effluent disposal.

As is evident throughout the literature review, there is a common belief among recent and past proponents of lagoons that algae are not a liability to a lagoon or receiving stream, because oxygen produced in photosynthesis is much greater than the oxygen ultimately consumed by algae. In fact, this is not the case.

Stumm and Morgan (49) have reported that the synthesis of algae cells may be represented by the following:

$$106\ CO_2 + 90\ H_2O + 16\ NO_3^- + PO_4^{\equiv} + \text{light energy}$$

$$C_{106}\ H_{180}\ O_{45}\ N_{16}\ P_1 + 154.5\ O_2 \ . \ . \ . \ .$$

It may be seen from the above equation that an abundance of oxygen would be available as a result of algae synthesis. This abundance is evidenced by high dissolved oxygen and super saturated lagoon effluent waters often reported in the literature. Because of these reports, algae-laden lagoon effluents have not been considered a liability to receiving water quality. However, the complete oxidation of the algae mass synthesized in the preceding equation also requires the complete amount of oxygen produced in the following equation:

$$C_{106}\ H_{180}\ O_{45}\ N_{16}\ P_1 + 154.5\ O_2$$

$$106\ CO_2 + 90\ H_2O + 16\ NO_3^- + PO_4^{\equiv} \ . \ . \ . \ .$$

It has been reported by Loehr and Stephenson (50) that

Nelson (51) indicated that only about 75 to 80 percent of the algal mass can be oxidized. Loehr and Stephenson (50) also reported that the net oxygen available after synthesis and degradation of algae cells was approximately 23 molecules of oxygen per algal cell synthesized, or only about 15 percent of that generated in photosynthesis. This amount could be increased if great quantities of algae were ingested by higher life forms in the receiving water, but the point is clear: sooner or later organic matter in the aquatic environment will exert an oxygen demand.

From this discussion and that presented in Section VI, it is evident that lagoons do not remove nutrients; rather, they recycle or convert them into other organic forms. These other forms are later capable of exerting their influence on receiving streams.

As state and Federal requirements become more restrictive and as greater portions of some nutrients must be removed before effluent is discharged into receiving waters, it would appear that lagoons, as a process, will be less and less able to comply with requirements without some form of supplemental treatment.

SIGNIFICANT CASE HISTORIES

Investigations on the fate and effect of lagoon effluent discharges are rare. Only in the last four years have investigators made specific studies on the impact of lagoon effluents on receiving water quality. Three significant case histories have appeared in the recent literature.

King, Tolmsoff, Atherton (52): These investigators reported that in lagoon design, careful attention is given to construction features such as depth, slope, stability, and inlet and outlet structures while little consideration has been given to the effect of lagoon effluent on receiving streams. The authors reported that regardless of the type of lagoon - facultative lagoon, an anaerobic cell followed by an aerobic pond or a tertiary lagoon - the effluent characteristically contains a significant concentration of algae. These algae, so abundant in most lagoons, give lagoon effluent its unique character (52). A significant load of energy-rich organic matter in the receiving stream is due to algae discharged from lagoons. However, a fundamental question exists: Do algae in lagoon effluents benefit the streams as oxygen generators, or are the algae an organic pollutant detrimental to the receiving water?

The investigators reported the lagoon effluent characteristics shown in Table 8. From this data it is evident that the dissolved fraction of the lagoon effluent is relatively non-biodegradable, exerting a BOD_5 of 8 mg/l and a BOD_{26} of only 44 mg/l. The BOD_5 and BOD_{26} due to the suspended solids in the lagoon effluent were reported to be 47 mg/l and 246 mg/l, respectively. Most of the oxygen demand associated with the lagoon effluent is then due to the suspended solids portion comprised of living organisms.

It is clear that BOD_5 is not an accurate measure of the oxygen demand of lagoon effluents. COD is a much better indicator of lagoon effluent oxygen demand although King's data indicates this is too low also.

The results of the King study clearly demonstrated that settleable solids and suspended algae in lagoon effluents can and do settle into pools within a very short distance of the lagoon outfall. During periods of low flow, this material accumulates to depths of several inches and undergoes successive periods of anaerobic decomposition. During periods of increased flow this material is scoured from the pool bottoms and carried downstream. Examination of macrobenthos below the outfall is typical of low oxygen conditions and poor water quality. Reoxygenation of the stream by diatom photosynthesis and surface aeration at the riffles is barely sufficient to satisfy the oxygen demand created by the facultative lagoon effluent. Insufficient oxygen is available to support a typical "clean water" biota in the stream. Examination of Table 13 (52) indicates again the close correlation between the COD and 26-day BOD, particularly for the suspended material (predominantly algal cells), and points out how misleading the standard 5-day BOD of an algae laden lagoon effluent may be in assessing lagoon impact on receiving streams.

If Bear Creek had a more sustained voluminous flow, the

TABLE 8

SUMMARY OF OXYGEN DEMAND OF LAGOON EFFLUENT BASED ON THE 26-DAY BOD DETERMINATIONS (52)

Parameter		Total Effluent	Dissolved		Suspended	
			Value	% of Total	Value	% of Total
I.	Initial COD, (mg O_2/l)	288	91	32	197	68
II.	Initial Volatile Solids, (mg/l)	282	126	45	156	55
III.	BOD-Values (mg O_2/l)					
	5-day	55	8	14	47	86
	10-day	94	14	15	80	85
	14-day	120	16	13	104	87
	26-day	290	44	15	246	85
IV.	26-day BOD Expressed as % of Initial COD	100%	48%		125%	
V.	COD Remaining on 26th Day (mg O_2/l)	142	77	54	65	46
VI.	% COD Remaining on the 26th Day	50%	85%		38%	

results would not be so obvious. One fact, however, does remain: that the added material, nutrients and algae, do have a demonstrable effect on lowering receiving water quality. How many Bear Creeks along a reach of river does it take to produce conditions unfit for the maintenance of "normal" or "natural" stream biota?

TABLE 9

AVERAGE DAILY LOADING OF BEAR CREEK FROM THE TWO MUNICIPAL LAGOONS GIVEN WITH THE ESTIMATED TOTAL LOAD FROM JULY 1, 1967 TO OCTOBER 1, 1967 (52)

COD	Dissolved	Suspended
Small Lag.	39.3 lbs (17.8 kg) O_2/day	84.2 lbs (38.1 kg) O_2/day
Large Lag.	66.9 (30.3 kg)	170.5 (77.3 kg)
Combined	106.2 lbs (48.1 kg) O_2/day	254.7 lbs(115.4 kg) O_2/day
7/1 - 10/1	9,770 lbs (4,425 kg)	23,400 lbs (10,610 kg)
26-Day Oxygen Demand		
Small Lag.	$>$ 18.8 lbs (8.5 kg) O_2/day	$>$ 103.0 lbs (46.7 kg) O_2/day
Large Lag.	$>$ 32.1 (14.5 kg)	$>$ 208.0 (94.2 kg)
Combined	$>$ 50.9 lbs (23.0 kg) O_2/day	$>$ 311.0 lbs(140.9 kg) O_2/day
7/1 - 10/1	$>$ 4,680 lbs (2,115 kg) O_2	$>$ 28,600 lbs (12,910 kg) O_2
Energy		
Small Lag.	39,400 kcal/day	156,000 kcal/day
Large Lag.	65,240	298,670
Combined	104,640 kcal/day	454,670 kcal/day
7/1 - 10/1	9,630,000 kcal	41,750,000 kcal

Missouri Water Pollution Board (53): Data provided by the Missouri Water Pollution Board (53) indicates that some deterioration of stream quality occurs downstream from lagoon outfalls. In many of the receiving streams there is such low flow that the effluent makes up 25-50 percent of the total flow past that point.

Lowered dissolved oxygen and increased BOD is seen below the outfall as compared to upstream flow. Only one study has been conducted (52) and these results suggest that similar results can be expected for all slow flow streams of the state which receive lagoon effluents.

State of Arkansas: The State of Arkansas provides what is probably the best operating and physical data on its lagoons of any state in the nation. Periodic visits are conducted by biologists and engineers, who remain at the lagoon station for several days.

The effects on receiving water have been identified and quantified to some extent by examination of stream invertebrate populations. Such examinations reveal that even though many of the lagoons investigated meet or exceed 85 percent BOD reduction in their operations, the invertebrate fauna below the outfall contain more pollution tolerant species than that of the water above.

In strict fairness to lagoons, the data also shows that the same result is obtained from standard treatment facilities, many of which have a poorer quality effluent than the lagoons.

Another point to be noted is the difference between stream water use patterns in the different states. Some states, such as Idaho, require that no effluent depress dissolved oxygen below 100 percent of saturation if the receiving water is used for the spawning or fry development of salmonoid fishes. In other states, such as Louisiana, up to a 50 percent of saturation reduction in D.O. is allowed.

Bain, McCarty, Robertson and Pierce (54): The San Joaquin River, during the summer months, is laden with phytoplankton as a result of nutrient enrichment by agricultural and municipal waste discharges. Oxidation pond effluent from the City of Stockton is discharged into the San

Joaquin River downstream from Stockton.

Data collected by the authors indicated that with increased depth of the river channel there was depressed atmospheric oxygenation due to diminished tidal velocity and larger channel cross section. The deepened channel acts as a stilling basin for algae grown in nutrient rich, warmer upstream river water and the lagoons at Stockton. These conditions were sufficient to create sustained oxygen depressions in the lower depths in summer and fall. These problems were directly traceable to lagoon effluents. The pond algae species are not the same as the river floral populations and can be expected to exist in the river as viable organisms for one or two days only. These species were identified to be exerting a major BOD and the cause of dissolved oxygen depressions in the San Joaquin River downstream from Stockton.

Examination of Table 10 shows that the Stockton lagoon effluent differed little from that of the standard treatment process. Nitrogen and phosphorus actually increased as did the coliform count. Even though the plant effluent MPN was previously reduced to acceptable numbers through chlorination, the period of retention in the lagoon allowed a significant regrowth. The generation of large quantities of green algae is seen to exert its influence not in the BOD_5 but rather in BOD_{30} which more closely approximates the COD.

That the algae from the lagoon were responsible for this growth is seen in Figure 23 which identifies the coccoid algae through its fluorescence (chlorophyll a), when compared to the total river microflora. The fate of these cells has been previously indicated and has been further documented by analysis of bottom samples.

THE STATES UNDERSTANDING OF THE IMPACT OF LAGOON EFFLUENT IN RECEIVING WATER QUALITY

An assessment of the impact of any lagoon effluent is dependent on characterizing the effluent, and the nature and flow of the stream. From the State survey, state engineers reported that many lagoons do not always achieve the stated objectives of secondary treatment in their state (see SECTION IV). They further indicated that many of the

TABLE 10

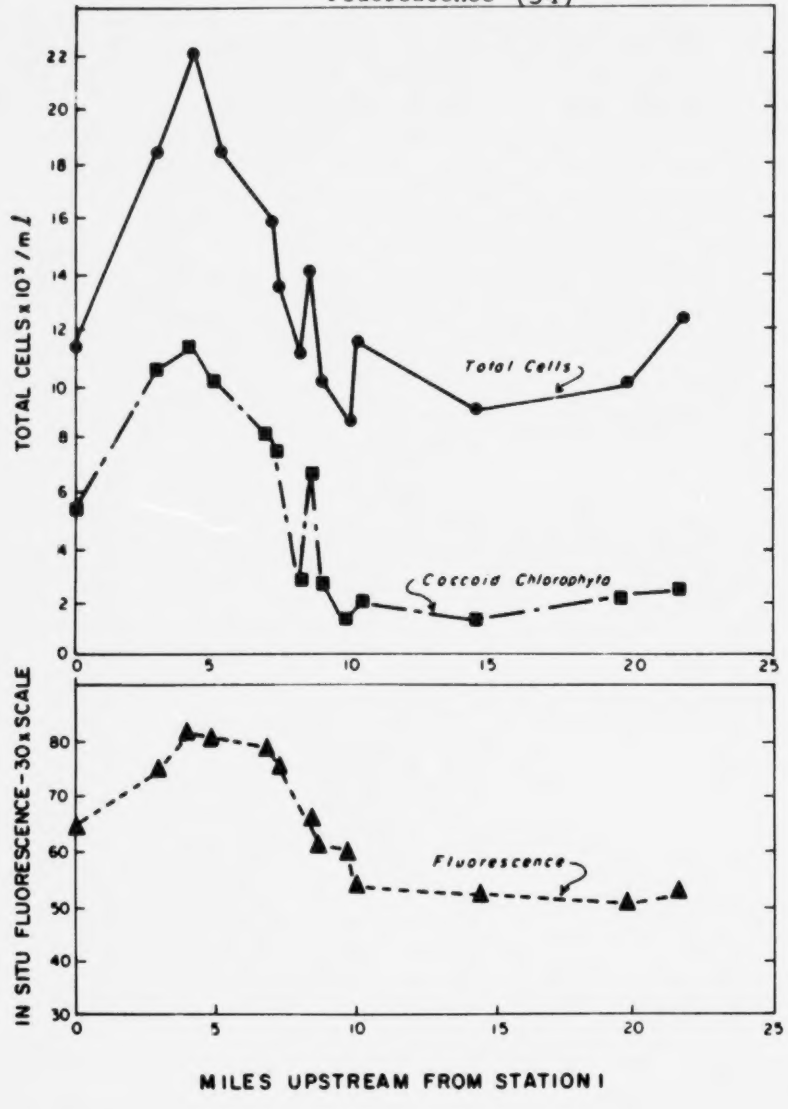
SUMMARY OF FLOW OF WASTE CONSTITUENTS THROUGH THE STOCKTON WASTEWATER TREATMENT PLANT* (54)

Constituent	Untreated Wastewater	Secondary Effluent	Pond Effluent
Total Nitrogen, Mg/l (N)	27.2	18.1	25.9
Total Phosphorus, mg/l (P)	7.5	5.0	5.2
Total Carbon, mg/l (C)	328	232	209
BOD, mg/l (5 day)	578	340	96
BOD, mg/l (30 day)	822	460	458
COD, mg/l	870	660	575
Chlorinated Hydrocarbon			
Organophosphate			
Fecal Coliform, MPN/100ml	60,000.	10	900
Phytoplankton, no./ml	--	--	211,000
Chlorophyll A, ug/l	--	--	270

*Average of four six-hour composite samples collected September 30 - October 1, 1969

FIGURE 23

Comparisons of Algal Populations Through Study Area Using Cell Counts and Chlorophyll Fluorescence (54)



lagoons which appear to meet or exceed the published standards for any given state do not have a sufficient body of reported measurements to identify the true quality of the effluent.

Those states which require periodic drawdown and subsequent retention of all lagoon water during critical times are satisfied that the releases, when made, are at such times that the receiving stream will not suffer demonstrable adverse effects. Very few, if any, studies have been conducted to verify this.

As indicated, a number of states "require" that samples be taken upstream and downstream from any sewage treatment facility outfall. Data of this type, if honestly collected and accurately analyzed, should provide information on effluent quality. In actual practice the contractor discovered such measurements are rarely made and many are of questionable analytical value with clear evidence of data being "dry-labed."

As indicated elsewhere in this report, the entire system of data collection, processing and retrieval is so bad that little valid data exists. However, this data is not necessary. The fact that many lagoons do produce an effluent of sufficient quality to qualify as adequate secondary treatment does not mitigate the fact that this effluent can have a potentially damaging effect to receiving stream quality.

SECTION VIII

ACKNOWLEDGEMENTS

The scope of this study required information from an extensive number of people and organizations. Gratitude is extended to all those who assisted the Contractor in obtaining needed information by providing time for interviews, and making available data and records. While the names of these contributors are too numerous to list individually, the participation of the following was essential to successful completion of this project.

Mr. Frank M. Middleton, Project Officer
Environmental Protection Agency
National Environmental Research Center
Cincinnati, Ohio

Environmental Protection Agency, Regional Offices

Key state engineers of 50 states

Outstanding educators and researchers of major universities across the country.

The following list includes key professional personnel whose efforts have contributed directly to the study of lagoon use and lagoon technology:

Project Principal: D. W. Ryckman, President

Project Manager: G. M. Barsom, Vice President

Project Coordinator: D. P. Clement, Environmental Engineer

Project Staff: R. M. Matter, Biologist; P. K. Feeney, Environmental Engineer; F. A. Brunner, Environmental Engineer; L. R. Novack, Technical Writer; M. R. Aron, Technical Writer; and P. A. Braden, Senior Typist

Project Review Committee: E. Edgerley; H. D. Tomlinson; F. K. Erickson; and S. J. Ryckman

SECTION IX

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APPENDIX A

LIST OF AGENCIES CONTACTED

TYPICAL RETA LETTERS TO STATES

REPRESENTATIVE CORRESPONDENCE FROM STATES

DATA SUMMARY SHEET

Table 1

LIST OF AGENCIES CONTACTED

STATE	AGENCY	CONTACT/TITLE
Alabama	Water Improvement Commission	Charles R. Horn, Asst. San. Eng.
Arizona	State Dept. of Health	Robert H. Follett A.C. Toncre, Public Health Eng.
Arkansas	Dept. of Pollution Control & Ecology	A.R. Sacrey, Proj. Consultant
California	Pacific Water Quality Admin, Southwest Regional Water Quality Control Board Water Resources Control Board	Richard C. Bain, Jr., San. Eng. William H. Crooks, Supervising Eng. Paul Bonderson George Gribkoff
Colorado	Dept. of Health, Water Pollution Control Division	Earl T. Balkum, P. E.
Florida	Dept. of Health & Rehabilitative Services, Div. of Health	Ralph H. Baker, Jr., Administrator, Wastewater Section
	University of Florida	Thomas deS. Furman
Georgia	Water Quality Control Board	J. Leonard Ledbetter, Dir. Water Quality Surveys Services
	Water Pollution Control Admin. Southeast Region	W. C. Mason John A. Little, Chie. Impoundment Studies John R. Thoman, Regional Dir.
Idaho	Environmental Improvement Division, Department of Health	Vaughn Anderson, Director
Illinois	Bureau of Water Pollution Control	Douglas Morton, Chief
	Hinde Engineering Company Environmental Protection Agency	James B. Neighbor, Vice President Thomas R. Wallin Supervisor, Wabash Basin Unit, Permit Section
Indiana	Water Quality Administration	Max T. Orem, Sanitary Engineer
	State Board of Health, Sewage Section	Oral H. Hert, Director
	Stream Pollution Control Board	Samuel L. Moore, Chief, Ind. Waste Perry E. Miller, Tech. Secretary Steve Kim Joseph Kreeger B. A. Poole, Tech. Secretary
Iowa	Dept. of Health Water Pollution Control Commission	Lavoy Haage, Sanitarian R. J. Schliekleman
Kansas	Ecodyne Corporation Environmental Health Services State Dept. of Health	Brian L. Goodman, Dir. Tech. Serv. Ralph Collie, Engineer Dick Pose, Engineer
Kentucky	Water Pollution Control Commission State Dept. of Health	Ralph C. Pickard, Director Walter C. Martin, Chief San. Eng.
Louisiana	Bureau of Environmental Health	James F. Coerver, Asst. Dir.
Maine	Bureau of Water Pollution Control Environmental Improvement Comm.	George C. Gormley, Chief
Maryland	Dept., Health & Mental Hygiene	William Bingley
Massachusetts	Water Resources Commission	John B. Casawsa, Asst. Dir.
Michigan	Dept. of Public Health Wastewater Section, Div., Engr.	Donald M. Pierce, Chief Maurie Redmond, Engineer
Minnesota	Nat'l Water Quality Laboratory, Fed. Water Pollution Control Admin. Pollution Control Agency Sewage Works Section	M.D. Lubratovich, Asst. Dir., Lab Management Lyle H. Smith, Asst. Exec. Dir. Edwin A. Smith
Mississippi	Air & Water Pollution Control Commission	Glen Wood, Jr., Acting Exec. Secy. Charles H. Chisolm, San. Eng.
Missouri	Burns & McDonnell Dept. of Public Health & Welfare, Water Pollution Board Water Pollution Control Board	J. E. White Charles A. Stiefemann, Field Activities Coordinator Bob Hivies Jack K. Smith, Exec. Secy. Ted Forrester, Field Engineer James H. Maurer, Field Engineer
	Ralston Purina	C.B. Smith, Dir., Tech. Services, Central Engineering
Montana	Environmental Sanitation Division of Water Pollution Control Section	C.W. Brinck Director D.G. Williams, Chief

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STATE	AGENCY	CONTACT/TITLE
Nebraska	Water Pollution Control Council, Environmental Health Services Water Pollution Control Council	T. A. Filipi, Chief
	Department of Health, Environmental Health Services	Terrence A O'Brien
Nevada	Dept. of Health, Welfare & Rehabilitation, Div. of Health	Wendell D. McCurry, Public Health Eng.
New Hampshire	School of Health Studies, University of New Hampshire	L.W. Slanetz, Dean
New Jersey	Water Resources Div., Environmental Protection	Harry H. Hughes, Principal Public Health Engineer
New Mexico	Environmental Improvement Agency Water Quality Section	Cole C. Harry, Administrator Phillip Barras
	Water Pollution Control Unit, Environmental Services Division Health & Social Services, Dept.	Max Feld, Supervisor
	Water & Liquid Waste Section	John R. Wright, Chief
New York	Commission of Environmental Conservation	Fred Vollner, Chief, Plant Assistance
North Carolina	Dept. of Water & Air Resources	Earle C. Hubbard, Asst. Director
	Institute for Environmental Health Studies, Univ. of N. Carolina	John W. Day, Jr.
North Dakota	Department of Health	W. Van Heuvelen, Exec. Officer
Ohio	Department of Health	Mr. Rosendal, Engineer Paul Flanigan, Engineer
	College of Engr. & Technology, Ohio University	Harry M. Kaneshige, Assoc. Prof.
Oklahoma	Dept. of Health, Water Quality Control Division	Charles D. Newton, Director
Oregon	Dept. of Environmental Quality	Kenneth H. Spies, Director
	U.S. Dept. of Interior, Federal Water Pollution Control Admin., Northwest Region	Kenneth A. Dostal, Chief, Food Wastes Research Branch
Pennsylvania	Dept. of Environmental Resources, Div. of Water Supply & Sewerage	Harry A. DeWire, Chief Facilities Section
South Carolina	Pollution Control Authority	H.J. Webb, Exec. Director
South Dakota	Dept. of Health, Div. of Sanitary Engineering	H.O. Allum, Public Health Scientist
Tennessee	Water Quality Control Division, Dept. of Public Health	S. Leary Jones, Director
	Division of Sanitary Engineering	Julian R. Fleming, Director John W. Saucier, San. Eng.
Texas	Dept. of Health	Ray Dingeis, Biologist Dick Whittington, Dir. Field Oper.
	Wastewater Treatment Division Dept. of Water Works, Dallas	Cecil H. Williams, Engineer
	City of Austin	D.F. Smallhorst, Chief Engineer
	Division of Wastewater Technology and Surveillance, Dept. of Health	R.B. Riddle, Chief Engineer
	Univ. of Texas, Collegeineering	Earnest F. Gloyna, Dean
	Fed. Water Pollution Control Admin., South Central Region	Hendon Crane, Dir., Office of Operations
Utah	Bureau of Environmental Health	H.M. Hurst, Asst. Director
Vermont	Agency of Environmental Conservation, Dept. of Water Resources	LeRoy Grunewald, San. Eng.
Virginia	Water Control Board	A. H. Paessler, Exec. Secretary
Washington	Water Pollution Control Commission	Russell K. Taylor, Associate Eng., Municipal Program
W. Virginia	Division of Water Resources, Dept. of Natural Resources	John Hall, Chief Edgar N. Henry, Chief
Wisconsin	Division of Environmental Protection Dept. of Natural Resources	Carl Blahlum Robert Derksen, District Eng. Mr. Benson, District Eng.
	Municipal Wastewater Section Dept. of Natural Resources	Robert W. Krill, Chief
Wyoming	Sanitary Engineering Services, Dept. of Health & Social Services	Arthur E. Williamson, Director

August 26, 1971

Mr. Walter A. Lyon, Director
Bureau of Sanitary Engineering
State Department of Health
Box 90
Harrisburg, Pa. 17120

Dear Mr. Lyon:

RETA is working with the EPA Water Quality Office on a report entitled "Lagoon Performance and the State of Lagoon Technology." We are presently canvassing state agencies in an effort to obtain all available up-to-date information. Your assistance in obtaining this material as outlined on the attached Data Summary Sheet would be very much appreciated.

The lagoon information from your state constitutes a key element in this Federal project and is vital to its successful completion. Recognizing that the compilation of this data is an imposition, we are providing your office with the attached sheet and a telephone data retrieval set-up.

To eliminate the need of replying in writing, a member of the RETA project team will contact you by telephone in approximately two weeks and transfer your information onto a similar Data Summary Sheet.

Thank you for your cooperation and valuable assistance.

Sincerely,

RYCKMAN, EDGERLEY, TOMLINSON
AND ASSOCIATES, INC.

Frederick A. Brunner, Ph.D.
Senior Associate

FAB:dbp
Enclosure

D. W. RYCKMAN
E. EDGERLEY, JR.
R. D. TOMLINSON
S. J. RYCKMAN

CONSULTANTS IN WATER, SOLIDS AND AIR RESOURCES

RYCKMAN · EDGERLEY · TOMLINSON and ASSOCIATES
520 CORONET BUILDING • [illegible] SOUTH MERAMEC AVENUE • SAINT LOUIS, MISSOURI 63105
TELEPHONE (314) 862-3424

August 24, 1970
RETA 550

Mr. H. J. Ongerth
State of California Health Department
2151 Berkeley Way
Berkeley, California 94704

Dear Mr. Ongerth:

As a result of correspondence between this office and William H. Crooks, Supervising Engineer of the California Regional Water Quality Control Board, we have been directed to request information on lagoons and lagoon performance from your office.

Confirming our telephone conversation of this morning, we will appreciate your sending us the following publications:

1. Raw Sewage Lagoons in California
2. Detention vs. Bacteriological Reduction in Sewage Lagoons,

along with any other information that you may have available on lagoon performance. We are interested in these publications because we are conducting a project for FWQA titled Lagoon Performance and the State of Lagoon Technology, and our primary concern is to collect the most recent reliable lagoon performance data available.

Please do not hesitate to contact me or Mr. Frank Middleton, FWQA Project Officer, if you have any questions.

Very truly yours,

RYCKMAN, EDGERLEY, TOMLINSON
AND ASSOCIATES, INC.

George M. Barsom

George M. Barsom, Sc.D.
Director of Research and Development

GMB/mcs

WILLIAM G. MILLIKEN, Governor
MAURICE S. REIZEN, M.D., Director

STATE OF MICHIGAN
DEPARTMENT OF PUBLIC HEALTH
3500 N. LOGAN, LANSING, MICHIGAN 48914

September 3, 1971

Mr. Frederick A. Brunner, Ph.D.
Ryckman, Edgerley, Tomlinson and Associates
500 Coronet Building
225 South Meramec Avenue
St. Louis, Missouri 63105

Dear Mr. Brunner:

Mr. John Vogt has referred your letter of August 26 to me for reply on the subject, "Lagoon Performance and the State of Lagoon Technology."

We appreciate the effort you are making in collecting information of this kind and certainly agree that the type of study you are making is needed and should be of great value to those who are involved with design and operation of treatment facilities. In Michigan we have collected a great deal of information from lagoons during periods of discharge and plan to continue to collect this and additional kinds of information. In reviewing your data summary sheet, however, particularly those relating to operational efficiencies, we find that this is too large a task to undertake at this time. Indeed, if we were to provide the kind of information covered by your total questionnaire, we would have to devote a great number of man days involving weeks of time to do it justice. If it is possible to provide adequate financial remuneration for this type of work we would be glad to undertake it within the limits of our capabilities.

I regret that I am not able to provide the desired information and I am sure that you would not want us to do this in a perfunctory manner based on generalities and oversimplification. Please let me know how we can be of assistance within this framework.

Very truly yours,

Donald M. Pierce

Donald M. Pierce, Chief
Wastewater Section
Division of Engineering

DMP/hc

MICHIGAN
THE GREAT LAKE STATE

"Equal Health Opportunity for All"

STATE of INDIANA

STREAM POLLUTION CONTROL BOARD

INDIANAPOLIS 46206

1330 West Michigan Street
633-4420

September 9, 1971

Frederick A. Brunner, Ph. D.
Senior Associate
Ryckman, Edgerley, Tomlinson & Associates
500 Coronet Building
225 South Meramec Avenue
Saint Louis, Missouri 63105

Dear Dr. Brunner:

Re: Lagoon Performance

This acknowledges your letter and attachments of August 26, 1971, which advised of your activity in preparing a report for the Environmental Protection Agency on subject matter and requested this office to prepare data summary sheet for transmittal of information to you via telephone.

The comprehensive data requested would require a detailed search of project files and in some cases contact with the industry. Staff limitations prohibit utilizing our time for this study. The data are in open files in this office and may be viewed during normal working hours with prior arrangements. If you desire to have a representative visit this office, please contact Mr. Samuel L. Moore, Chief, Industrial Waste Disposal Section, telephone number 317 - 633-5278, for a convenient time.

Very truly yours,

Perry E Miller

Perry E. Miller
Technical Secretary

OHHert/lbw
cc: Samuel L. Moore

STATE OF NEVADA
DEPARTMENT OF HEALTH, WELFARE, AND REHABILITATION
DIVISION OF HEALTH
CARSON CITY, NEVADA 89701

RECEIVED
JUL 27 1970
RETA, INC.

July 20, 1970

Phillip K. Feeney
Project Engineer
Ryckman, Edgerley, Tomlinson & Associates
500 Coronet Building
225 South Meramec Avenue
Saint Louis, Missouri 63105

Dear Mr. Feeney:

In reply to your letter to Mr. Karl Harris, are the following answers to your questions:

1. Approximately 15 excluding aerated lagoons.
2. Monthly. None.
3. Bureau of Environmental Health. Ten State Standards.
4. None.
5. Winter operation in northern part of State.
6. No. Some areas require a high degree of treatment and in some areas the degree of treatment is not critical as long as some treatment is provided and no effluent is allowed to return to the stream.

Sincerely,

Wendell D. McCurry

Wendell D. McCurry
Public Health Engineer

WDM/gm

THE UNIVERSITY OF TEXAS AT AUSTIN
COLLEGE OF ENGINEERING
AUSTIN, TEXAS 78712

Office of the Dean

July 13, 1970

RECEIVED
JUL 16 1970
RETA, INC.

Mr. Phillip Feeney, Project Engineer
Ryckman, Edgerley, Tomlinson & Associates
500 Coronet Bldg.
225 South Meramec Avenue
St. Louis, Missouri 63105

Dear Sir:

Reference is made to your request regarding reports entitled "Lagoon Performance and The State of Lagoon Technology". Last year I prepared a very lengthy document for the WHO. You might be able to get a copy of this by writing to Mr. Luis Orihuela, WHO, Geneva, Switzerland. Also, we are completing some very detailed pond studies here in Austin but this report will not be released until October.

Sincerely,

Earnest F. Gloyna
Dean

EFG:sm

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STATE OF **COLORADO** DEPARTMENT OF **HEALTH**
4210 EAST 11TH AVENUE • DENVER, COLORADO 80220 • PHONE 388-6111
R. L. CLEERE, *M.D., M.P.H., DIRECTOR*

July 16, 1970

RECEIVED
JUL 20 1970
[illegible] INC.

Mr. Phillip K. Feeney, Project Engineer
Ryckman-Edgerly-Tomlinson and Associates
500 Coronet Building, 225 South Meramec Avenue
Saint Louis, Missouri 63105

Re: Sewage Lagoons

This is a reply to your letter of July 7, 1970. To answer your specific questions, we require monthly operator reports from all domestic sewage treatment works, activated sludge, trickling filter lagoons, etc. Also, our District Engineers make two-four visits annually to all plants, including lagoons. We run grab samples on all treatment works, approximately once a year. For lagoons, we are interested in: color, odor, algae, raw influent BOD, effluent BOD and coliform of the influent and effluent. Also, we are interested in the presence or absence of bottom weed growth, shore-line growth, duck weed, and a minimum of three feet water level at all times.

As regards cost data, our experience shows that lagoon systems are cheaper to construct and operate than other types of treatment works. They have their real value in the non-mountainous areas of the State. Many small towns of 500-2000 P.E. would not have systems today were lagoons disapproved. We have no failures where our engineering criteria has been used. We call for the BOD loading to not exceed 0.1 lb BOD/day/1000 C.F. of water volume in a tight pond with a water depth of not less than 3 feet nor more than 5 feet (without mechanical aeration).

We hope this is of some value to your research. If we can be of further assistance, please advise.

FOR DIRECTOR, WATER POLLUTION CONTROL DIVISION

Earl T. Balkum, P.E.
Domestic Waste Consultant

ETB:mgc

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

L. P. Voigt
Secretary

North Central District
P. O. Box 311
Wisconsin Rapids, Wisconsin 54494

715-423-5670

February 18, 1972

IN REPLY REFER TO: 3420

R.E.T.A.
12161 Lackland Road
St. Louis, Missouri 63141

ATTENTION: Mr. Dave Clement

Gentlemen:

Included are results of sampling which you requested via Bob Benson of our Madison office.

The treatment facilities are two-cell stabilization ponds located in Marathon, Wood, and Portage Counties of Wisconsin. None of these receives industrial wastes. The samples are grab samples of the effluent. In the case of No. 4 which doesn't get quite full enough to have an effluent, samples were obtained from the final pond adjacent to the outfall manhole.

Except in the case of No. 1, effluents from these treatment units dissipate before reaching the surface water. Enclosed Page No. A-40 from our 1970 river basin reports includes sampling data of the receiving stream of Pond No. 1. The effluent from this pond flows several hundred feet in a drainage course before reaching the stream sampled (Mill Creek).

Very truly yours,
ENVIRONMENTAL PROTECTION SECTION

Robert R. Derksen, P.E.
District Engineer

RRD:jmm

STATE OF ALABAMA
WATER IMPROVEMENT COMMISSION
ROOMS 324-326
STATE OFFICE BUILDING
MONTGOMERY 4, ALABAMA

IRA L. MYERS, M. D.
CHAIRMAN

ARTHUR N. BECK
TECHNICAL SECRETARY

RECEIVED
AUG 24 1970
RETA, INC.
#

August 20, 1970

Mr. Phillip K. Feeney, Project Engineer
Ryckman, Edgerley, Tomlinson, and Associates, Inc.
225 South Meramec Avenue
St. Louis, Missouri 63105

Dear Mr. Feeney:

Enclosed in the information requested in your letter of July 2, 1970.

1. In reply to your first question a county by county summary of the lagoons within the state, including the acreage is enclosed. This list does not include the various industrial treatment lagoons, schools, or trailer courts. Industrial and private lagoons do, however, require the approval of this office.

2. (a) Normally we request a day by day report of effluent data, submitted at monthly intervals for activated sludge and trickling filter plants. This report should include such information as flows, suspended solid and BOD contents, pH, alkalinity, and DO in certain instances.

   (b) No effluent data is required of lagoons, due to the degree of training of the operating personnel, especially in the area of performing the analyses. This is often true of the smaller treatment plants also.

3. The design of all treatment facilities must meet certain minimum requirements set forth by this office. Enclosed are our requirements for lagoon construction in this state. Federally financed projects must also be approved by FWQA.

4. Our data indicate that the construction cost of a lagoon in Alabama amounts to approximately $7000/acre. Maintenance costs vary with the size of the pond, the amount of grass-cutting required, etc. A general range is $500-2000/year depending on the above and other factors.

5. Most problems encountered in this state with lagoon operation revert to poor maintenance practices. Specifics include improper grassing of dikes which allows erosion into the lagoon, grease build-up in the outlet area, vegetation in the form of either duckweed or marginal growth along the banks, and bluegreen algae build-up due to the lack of proper surface agitation. Another problem quite common is the inadequate knowledge of the operators as to the number of customers added to the original system. This has caused some difficulty and,

in one case, even septic conditions have resulted.

6. The lagoon method of treatment is acceptable by this office as long as construction conforms to the standards enclosed. This method of treatment has certain distinct advantages in this state in that it is economical to construct and to operate. Although the land area required is larger than for a conventional plant, it is more easily obtained than the necessary capital for plant construction. This is especially true for the smaller municipalities for which the method is very prominent. Also, soil conditions as well as year-around climatic conditions in Alabama are conducive to lagoon treatment methods.

7. A trend in lagoon treatment in this state,and possibly a requirement in the very near future, is the use of multi-cell lagoons to provide more efficient treatment.

We hope the enclosed information will be of use to you and invite any further inquirie that you may have.

Yours very truly,

Charles R. Horn

Charles R. Horn
Assistant Sanitary Engineer
Water Improvement Commission

CRH/dtc

Enclosures

COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF ENVIRONMENTAL RESOURCES
P. O. Box 2351
Harrisburg 17120

September 17, 1971

Frederick A. Brunner, Ph.D.
Senior Associate
Ryckman, Edgerley, Tomlinson and Associates, Inc.
500 Coronet Building
225 South Meramec Avenue
Saint Louis, Missouri 63105

Dear Dr. Brunner:

Your letter of August the 26th., 1971 to Mr. Walter A. Lyon has been referred to this office. I am sorry that we are unable to furnish you the information requested since we do not have the clerical staff to collect the information and prepare the answer. We have a number of these installations in Pennsylvania, but do not keep complete records of their performance. We do inspect and do have some information which can be obtained in our Regional Office or by direct contact with the owner. If we can be of any other help to you, please contact us.

Sincerely,

Harry A. DeWire, Chief
Facilities Section
Division of Water Supply and Sewerage

South Dakota
State Department of Health
ROBERT H. HAYES, M.D., STATE HEALTH OFFICER
Pierre

July 13, 1970

In Reply
Refer To: 7.1

RECEIVED
[illegible] 1970
[illegible] INC.

Phillip K. Feeney, Project Engineer
Ryckman, Edgerley, Tomlinson, & Associates
500 Coronet Building
225 South Meramec Avenue
St. Louis, Missouri 63105

Dear Mr. Feeney:

Mr. Carl has asked me to provide the information you have requested.

Conventional treatment plants are required to submit a monthly operating report with performance tests; most stabilization pond installations are required to submit a quarterly summary of monthly operation reports. For most ponds, no performance tests are required, except at the discretion of the Committee on Water Pollution when the ponds are overflowing or are being drawn down for winter storage. A few of the larger stabilization pond installations, such as Huron, and all polishing pond installations are required to submit monthly operation reports with performance data. Except in unusual circumstances, performance data include D.O., B.O.D., T.S.S., pH, and fecal coliforms. Copies of the report forms used are enclosed.

The cost data that are available are included in the publication, "Wastewater Stabilization Ponds in South Dakota" previously sent to you.

If we can be of further assistance, please let us know.

FOR THE DIVISION OF SANITARY ENGINEERING

Sincerely,

M. O. Allum

M. O. Allum
Public Health Scientist

MOA:jb
Enclosure

DATA SUMMARY SHEET

Person Interviewed______________________________

Lagoon Name/Location______________________________

PHYSICAL PARAMETERS:

Number of cells______________________________
Area______________________________
Volume______________________________
Depth______________________________
Flow______________________________
Actual loading______________________________
By whom were lagoon(s) designed?______________________
____
What is the basis for design?
(State Health Dept., Pollution Control Board, etc.)
____
What agencies were responsible for approval of the design?______________________________
____

USE:

	(population or pop. equivalent)	
___Municipal	______________	___Secondary
___Industrial	______________	___Tertiary
___Combination	______________	___Complete

Type of pretreatment?______________________________

CLASSIFICATION:

____ Facultative
____ Aerated
____ Anaerobic
____ Oxidation Ditch

Were Mechanical Aerators Used? ____________

OPERATION:

Design Efficiencies: BOD ____
COD ____
SS ____

Operating Efficiencies:

		Effluent	
	Influent	Filtered	Unfiltered
BOD			
COD			
SS			
N			
P			

	% Removal	
	Filtered	Unfiltered
BOD		
COD		
SS		
N		
P		

Aesthetic Quality:

	Heavy	Moderate	Light	None
H_2S				
Algae Mats				
Odors				
Shore growth (weeds)				
Insect & Rodent				
Colored Effluents				

What is the condition of receiving stream?

Flow____________________________________

Dilution capacity__________________________

Color___________________________________

Other___________________________________

COSTS:

Total Capital Investment________Amortized:$_____/yr.

% Federal__________

% State____________

% Local____________

Operating Costs__________________ $_____/yr.

Total Cost $_____/yr.

Are qualified personnel retained to operate the system?

Number____________________________________

Frequency__________________________________

Qualifications______________________________

What is suggested to improve quality of operation?

1) ______________________________

2) ______________________________

3) ______________________________

4) ______________________________

Describe additional problems, if any, and solutions.

1) ______________________________

____

2) ______________________________

____

3) ______________________________

____

What are your reasons for choosing lagoons over other conventional treatment processes? ______________________________

____

____

Are you satisfied with performance? Yes____ No____

Will you build more (additional) lagoons?

Yes____ No____

Do you consider a lagoon as secondary treatment?

Yes____ No____

Why or why not? ______________________________

____

____

What is the basis of your opinion? ______________________________

____

____

____

Do you consider lagoons adequate to meet the treatment needs of your state?____________________

____

____

____

____

(Affix Operational Data Sheets and Submit with Summary)

APPENDIX B

OPERATING DATA

TABLE 1

BIOCHEMICAL OXYGEN DEMAND (BOD) REDUCTION IN FACULTATIVE OXIDATION LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE*
2	--AZ	150	44	70.7	73
3	--AZ	170	100	41.2	73
4	--AZ	270	N.O.[1]	--	73
5	--AZ	350	56.5	83.8	73
6	--AZ	80	80	0	73
7	--AZ	300	100	66.7	73
8	--AZ	300	35	88.5	73
9	--AZ	290	150	56.4	73
10	--NM	360	95	67.6	73
11	--NM	105	34	67.6	73
12	--NM	400	88	78.0	73
13	--NM	370	70	81.1	73
14	--NM	360	86	76.1	73
15	--NM	290	72	75.2	73
16	--NM	290	51	82.4	73
17	--NM	260	60	77.0	73
18	--CA	203	14(c)[2]	93.0	74
21	--CA	119	9(c)	92.4	74
26	--CA	143	34	76.2	75
27	--CA	93	6	93.7	75
28	--CA	57	26	54.4	75
36	--IL	226	32.2	85.8	76
44	--LA"A"	236	60	74.6	77
45	--LA"B"	244	58	76.2	77
46	--MS #1	188	45	76.1	65
47	--MS #2	188	55	70.7	65
54	--MO #1	266	34	87	30
55	--MO #2	266	38	86	30
56	--MO #3	266	48	82	30
57	--MO #4	266	49	81	30
58	--MO #5	266	47	82	30
59	--MO #6	266	30	89	30
60	--MO #1	268	53	80	56
61	--MO #3	268	50	81	56
62	--MO #4	268	40	85	56
63	--MO #5	268	44	84	56
66	--MO	206	33	84	67
69	--NE	78	20	88	78

*References page 164.

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
75	--ND	384	45	89	6
76	--OH #1	238	57	76	66
77	--OH #3	238	97	59	66
78	--OK	225	51	77	79
79	--OK	224	58	74	79
80	--OK	238	24	90	79
81	--OK	228	38	83	79
82	--OK	264	45	83	79
83	--OK	238	43	82	79
84	--OK	226	40	82	79
86	--OK	--	N.O.	--	80
87	--OK	162	37	77	80
88	--OK	--	N.O.	--	80
89	--OK	--	N.O.	--	80
90	--OK	165	28	83	80
91	--OK	--	N.O.	--	80
92	--OK	--	24	--	80
93	--OK #2	--	N.O.	--	80
99	--TX #1	162	42.5	74	8
103	--WI	153	9.3	93	81
104	--WI	243	45	85	81
119	--UT	90	9	90	82
500	--TX	140	11	92	61
	--TX	--	21	--	61
	--TX	--	45	--	61
	--TX	--	30	--	61
501	--TX	120	75	38	61
	--TX	160	170	(6)	61
	--TX	65	0	--	61
502	--TX	95	45	53	61
	--TX	135	50	63	61
	--TX	120	155	(29)	61
	--TX	165	50	70	61
	--TX	80	30	63	61
503	--TX	220	17	92	61
504	--TX	90	35	61	61
	--TX	33	30	9	61
	--TX	135	105	22	61
	--TX	135	105	22	61
	--TX	110	75	32	61
	--TX	90	20	78	61

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
505	--TX	250	9	96	61
	--TX	130	190	(46)	61
	--TX	530	75	86	61
506	--TX	--	170	--	61
	--TX	--	45	--	61
	--TX	--	50	--	61
	--TX	--	155	--	61
	--TX	--	60	--	61
	--TX	--	--	--	61
507	--TX	215	17	92	61
	--TX	570	65	89	61
	--TX	315	0	100	61
508	--TX	--	45	--	61
509	--TX	320	120	63	61
	--TX	320	100	69	61
510	--TX	85	60	29	61
	--TX	90	40	56	61
	--TX	13	14	(8)	61
511	--TX	--	15	--	61
	--TX	230	75	67	61
	--TX	450	65	88	61
511	--TX	230	40	83	61
	--TX	180	40	78	61
	--TX	160	17	89	61
532	--CO	218	12	94	62
533	--CO	194	5	97	62
534	--CO	192	30	84	62
535	--CO	122	12	90	62
536	--CO	355	36	89	62
537	--CO	322	29	91	62
546	--IA #1	--	70	--	63
	--IA #2	--	25	--	63
	--IA #3	--	25	--	63
	--IA #4	--	25	--	63
547	--IA #1	--	95	--	63
	--IA #2	--	25	--	63
	--IA #3	--	95	--	63
	--IA #4	--	25	--	63
548	--IA #1	--	110	--	63
	--IA #2	--	25	--	63
	--IA #3	--	55	--	63
	--IA #4	--	35	--	63

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
549	--IA #1	--	150	--	63
	--IA #2	--	25	--	63
	--IA #3	--	30	--	63
	--IA #4	--	45	--	63
550	--IA #1	--	30	--	63
	--IA #2	--	30	--	63
	--IA #3	--	25	--	63
	--IA #4	--	30	--	63
551	--MO	192	72	63	64
552	--MO	320	35	89	64
553	--MO	14	15	89	64
554	--MO	220	20	91	64
555	--MO	136	25	82	64
556	--MO	210	35	17	64
557	--MO	370	79	79	64
558	--MO	250	27	89	64
559	--MO	70	18	74	64
560	--Mo	272	22	92	64

LEGEND

(c) = filtered before analysis
( ) = negative number
N.O.= no overflow
Units are in mg/l

TABLE 2

CHEMICAL OXYGEN DEMAND (COD) REDUCTION IN FACULTATIVE OXIDATION LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
18	--CA	452	70(c)	84.5	74
45	--LA"B"	435	297	43.8	77
69	--NE	220	152	67.4	78
86	--OK	--	N.O.	--	80
87	--OK	330	296	10	80
88	--OK	--	N.O.	--	80
89	--OK	--	N.O.	--	80
90	--OK	531	257	52	80
91	--OK	--	N.O.	--	80
92	--OK	--	197	--	80
93	--OK #2	--	N.O.	--	80

LEGEND

(c) = filtered before analysis
N.O.= no overflow
Units are in mg/l

TABLE 3

SUSPENDED SOLIDS (SS) REDUCTION IN FACULTATIVE OXIDATION LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
2	--AZ	136	80	41.2	73
3	--AZ	96	56	41.7	73
4	--AZ	140	N.O.	--	73
5	--AZ	280	66	76.4	73
6	--AZ	79	84	(6.3)	73
7	--AZ	299	90	69.9	73
8	--AZ	242	92	62.0	73
9	--AZ	344	124	64.0	73
10	--NM	240	202	15.8	73
11	--NM	136	360	(178.0)	73
12	--NM	292	236	19.2	73
13	--NM	364	124	65.9	73
14	--NM	204	276	(35.3)	73
15	--NM	164	84	48.8	73
16	--NM	52	64	(23.1)	73
17	--NM	112	68	39.3	73
18	--CA	116	90(c)	45.8	74
19	--CA	138	54(c)	60.9	74
46	--MS #1	230	100	56.5	65
47	--MS #2	230	100	56.5	65
66	--MO	129	62	52.0	67
69	--NE	124	92	65.1	78
76	--OH #1	646	537	17.1	66
77	--OH #3	646	615	4.7	66
86	--OK		N.O.		80
87	--OK	317	171	46	80
88	--OK		N.O.		80
89	--OK		N.O.		80
90	--OK	360	96	73	80
91	--OK		N.O.		80
92	--OK		92		80
93	--OK #2		N.O.		80
99	--TX	145	125	14	8
103	--WI		36		81
104	--WI		47		81

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
500	--TX	104	92	12	61
	--TX	--	52	--	61
	--TX	--	66	--	61
	--TX	--	89	--	61
501	--TX	107	67	37	61
	--TX	180	143	21	61
	--TX	64	--	--	61
502	--TX	76	117	(54)	61
	--TX	171	46	73	61
	--TX	166	114	31	61
	--TX	245	29	88	61
	--TX	234	75	68	61
503	--TX	730	22	97	61
504	--TX	59	50	18	61
	--TX	22	66	(200)	61
	--TX	53	47	11	61
	--TX	53	47	11	61
	--TX	106	25	76	61
	--TX	198	32	84	61
505	--TX	195	--	--	61
	--TX	29	63	(117)	61
	--TX	142	12	92	61
506	--TX	--	--	--	61
	--TX	--	32	--	61
	--TX	--	32	--	61
	--TX	--	135	--	61
	--TX	--	120	--	61
	--TX	--	100	--	61
507	--TX	45	64	42	61
	--TX	30	120	(300)	61
	--TX	313	--	--	61
508	--TX	--	44	--	61
509	--TX	255	138	46	61
	--TX	262	103	61	61
510	--TX	34	83	(144)	61
	--TX	158	59	63	61
	--TX	24	69	(188)	61
511	--TX	--	393	--	61
	--TX	225	132	41	61
	--TX	195	265	(36)	61
	--TX	97	68	30	61
	--TX	114	222	(7)	61
	--TX	145	38	74	61

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
532	--CO	228	32	86	62
533	--Co	113	17	85	62
534	--CO	267	49	82	62
535	--CO	174	17	90	62
536	--CO	256	135	47	62
537	--CO	240	95	60	62

LEGEND

(c) = filtered before analysis
( ) = negative number
N.O.= no overflow
Units are in mg/l

TABLE 4

TOTAL NITROGEN REDUCTION IN FACULTATIVE OXIDATION LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
18	--CA	35	20(c)	42.8	74
21	--CA	29	19.7(c)	32.1	74
54	--MO #1	160.7	11.6	93	30
55	--MO #2	160.7	13.8	92	30
56	--MO #3	160.7	18.5	89	30
57	--MO #4	160.7	17.4	89	30
58	--MO #5	160.7	17.1	89	30
59	--MO #6	160.7	11.7	93	30
60	--MO #1	152	12.9	97	56
61	--MO #3	152	10.8	93	56
62	--MO #4	152	9.6	94	56
63	--MO #5	152	9.9	93	56
76	--OH #1	20.4	15.8	22	66
77	--OH #3	20.4	19.8	3	66
78	--OK	52.4	25.3	52	79
79	--OK	44.4	26.5	40	79
80	--OK	50.5	17.4	66	79
81	--OK	55.6	26.3	53	79
82	--OK	60.2	26.4	56	79
83	--OK	48.2	23.8	51	79
84	--OK	59.6	30.8	48	79
86	--OK	--	N.O.	--	80
87	--OK	35.7	28.3	21	80
88	--OK	--	N.O.	--	80
89	--OK	--	N.O.	--	80
90	--OK	58.1	20.6	65	80
91	--OK	--	N.O.	--	80
92	--OK	--	10.1	--	80
93	--OK #2	--	N.O.	--	80
103	--WI	--	5.0	--	81
104	--WI	--	17.0	--	81

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
500	--TX	--	15	--	61
	--TX	--	13	--	61
	--TX	--	37	--	61
	--TX	--	13	--	61
501	--TX	--	360	--	61
	--TX	--	259	--	61
	--TX	--	0	--	61
502	--TX	--	198	--	61
	--TX	--	260	--	61
	--TX	--	304	--	61
	--TX	--	279	--	61
	--TX	--	219	--	61
503	--TX	--	92	--	61
504	--TX	--	69	--	61
	--TX	--	15	--	61
	--TX	--	58	--	61
	--TX	--	58	--	61
	--TX	--	28	--	61
	--TX	--	21	--	61
505	--TX	--	60	--	61
	--TX	--	249	--	61
	--TX	--	269	--	61
506	--TX	--	0	--	61
	--TX	--	112	--	61
	--TX	--	194	--	61
	--TX	--	43	--	61
	--TX	--	180	--	61
	--TX	--	0	--	61
507	--TX	--	62	--	61
	--TX	--	39	--	61
	--TX	--	0	--	61
508	--TX	--	13	--	61
509	--TX	--	339	--	61
	--TX	--	144	--	61
510	--TX	--	214	--	61
	--TX	--	146	--	61
	--TX	--	75	--	61
511	--TX	--	56	--	61
	--TX	--	122	--	61
	--TX	--	171	--	61
	--TX	--	64	--	61
	--TX	--	15	--	61
	--TX	--	127	--	61

LEGEND

(c) = filtered before analysis

N.O.= no overflow

Units are in mg/l

TABLE 5

TOTAL PHOSPHATE (PO_4) REDUCTION IN FACULTATIVE OXIDATION LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
21	--CA	34	32	5.6	74
36	--IL	17.0	10.4	38.8	76
54	--MO #1	42.6	8.2	80	30
55	--MO #2	42.6	9.7	76	30
56	--MO #3	42.6	13.8	67	30
57	--MO #4	42.6	12.8	70	30
58	--MO #5	42.6	12.8	70	30
59	--MO #6	42.6	9.1	78.6	30
60	--MO #1	44.0	10.8	93	30
61	--MO #3	44.0	8.0	82	56
62	--MO #4	44.0	6.9	84	56
63	--MO #5	44.0	6.6	85	56
76	--OH #1	6.0	5.6	7	56
77	--OH #3	6.0	5.4	10	66
78	--OK	65.9	18.0	24	66
79	--OK	81.8	26.4	68	79
80	--OK	73.4	34.2	53	79
81	--OK	83.0	38.2	54	79
82	--OK	82.5	37.5	55	79
83	--OK	81.3	39.5	51	79
84	--OK	88.4	38.8	56	79
86	--OK	--	N.O.	--	79
87	--OK	19.5	51.9	(166)	80
88	--OK	--	N.O.	--	80
89	--OK	--	N.O.	--	80
90	--OK	22.0	3.7	83	80
91	--OK #2	--	N.O.	--	80
92	--OK	--	10.1	--	80
93	--OK	--	N.O.	--	80
					80

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
500	--TX	--	52	--	61
	--TX	--	75	--	61
	--TX	--	54	--	61
	--TX	--	2	--	61
501	--TX	--	340	--	61
	--TX	--	620	--	61
	--TX	--	0	--	61
502	--TX	--	140	--	61
	--TX	--	560	--	61
	--TX	--	480	--	61
	--TX	--	500	--	61
	--TX	--	260	--	61
503	--TX	--	170	--	61
504	--TX	--	105	--	61
	--TX	--	70	--	61
	--TX	--	330	--	61
	--TX	--	190	--	61
	--TX	--	95	--	61
505	--TX	--	350	--	61
	--TX	--	360	--	61
	--TX	--	410	--	61
506	--TX	--	0	--	61
	--TX	--	490	--	61
	--TX	--	540	--	61
	--TX	--	465	--	61
	--TX	--	430	--	61
507	--TX	--	170	--	61
	--TX	--	240	--	61
	--TX	--	0	--	61
508	--TX	--	2	--	61
509	--TX	--	550	--	61
	--TX	--	365	--	61
510	--TX	--	220	--	61
	--TX	--	210	--	61
	--TX	--	85	--	61
511	--TX	--	220	--	61
	--TX	--	150	--	61
	--TX	--	150	--	61
	--TX	--	130	--	61
	--TX	--	31	--	61
	--TX	--	145	--	61

LEGEND
N.O.= no overflow
( ) = negative number
Units are in mg/l

TABLE 6

FECAL COLIFORM REDUCTION FACULTATIVE OXIDATION LAGOONS

CASE	LOCATION	INFLUENT X10^6/100 ml	EFFLUENT X10^3/100 ml	% REMOVAL	REFERENCE
1	--AL		330		83
30	--GA	1.4	1000		84
31	--GA	22.0	35		84
32	--GA	6.8	2		84
33	--GA	3.3	9.3		84
34	--GA	44.0	200		84
35	--GA	26.5	71		84
48	--MS I	32.2	109.8		84
49	--MS II	24.5	128.0		84
50	--MS	15.0	47		84
51	--MS	38.3	270		84
52	--MS	26.0	1.1		84
532	--CO	24.0	24		62
533	--CO	300	5		62
534	--CO	22	22		62
535	--CO	2.2	2.2		62
536	--CO	22	50		62
537	--CO	30	30		62

TABLE 7

BIOCHEMICAL OXYGEN DEMAND (BOD) REDUCTION IN ARTIFICIALLY AERATED LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
40	--IA #1	667	57	91.5	63
41	--IA #2	57	33	42.1	80
94	--OK	440	26	94	85
95	--OR	190	45	76	86
100	--WA	820	196	76	68
107	--ONT	403	244	44	87
108	--ONT	477	48	91.5	88
109	--ID	--	32	--	69
110	--IL	174	29	83	69
53	--MO	140	33	76	69
67	--MO #1	182	89	32	89
68	--MO #2	89	43	67	68
98	--TN	569(ND)	3	62	61
106	--ONT	510(ND)	158	64	61
522	--TX	165	135	18	61
	--TX	--	245	--	61
	--TX	270	160	41	61
523	--TX	185	8	96	61
	--TX	185	8	96	61
	--TX	70	55	21	61
	--TX	70	55	21	61
524	--TX	270	50	81	61
	--TX	250	30	88	61
	--TX	345	70	80	61
	--TX	80	50	38	61
525	--TX	530	120	77	61
	--TX	525	50	90	61
	--TX	310	35	88	61
	--TX	320	135	58	61
526	--TX	270	40	85	61
	--TX	160	40	75	61
	--TX	240	70	71	61
	--TX	370	30	92	61
	--TX	300	200	33	61
527	--TX	290	150	48	61
	--TX	--	175	--	61

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
528	--TX	380	17	96	61
	--TX	335	60	82	61
	--TX	--	20	--	61
	--TX	--	40	--	61
	--TX	150	18	88	61
	--TX	90	30	67	61
529	--TX	115	65	43	61
	--TX	45	35	22	61
	--TX	205	215	(5)	61
	--TX	105	17	84	61
	--TX	--	30	--	61
530	--TX	350	140	60	61
	--TX	--	75	--	61
	--TX	235	20	91	61
531	--TX	--	25	--	61
	--TX	--	24	--	61
	--TX	--	24	--	61
	--TX	160	11	93	61
538	--CO	150	12	92	62
539	--CO	130	18	86	62
540	--CO	204	29	86	62
541	--CO	246	27	89	62
542	--CO	194	13	95	62

LEGEND

( ) = negative number
(ND)= not domestic - includes industrial wastes
Units are in mg/l

TABLE 8

CHEMICAL OXYGEN DEMAND (COD) REDUCTION IN ARTIFICIALLY AERATED LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
40	--IA #1	1330	228	82.8	63
41	--IA #2	228	151	33.8	63
94	--OK	1010	235	77	80
100	--WA	1420	580	59	86
109	--ID	--	120	--	87
53	--MO	389	194c^1	50	69
67	--MO #1	474	326	35	69
68	--MO #2	326	218	33	69

TABLE 9

SUSPENDED SOLIDS REDUCTION IN ARTIFICIALLY AERATED LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
40	--IA #1	511	76	85.1	63
41	--IA #2	76	37	51.3	63
94	--OK	364	114	69	80
95	--OR	138	52	62	85
100	--WA	340	580	(71)	86
107	--ONT	196	327	(68)	68
108	--ONT	400	58	85	68
109	--ID	--	36	--	87
110	--IL	134	54	63	88
53	--MO	175	88(c)	50	69
67	--MO #1	200	130	25	69
68	--MO #2	130	78	40	69
98	--TN	600(ND)	7	99	89
106	--ONT	158	213	(44)	68
522	--TX	133	75	44	61
	--TX	--	135	--	61
	--TX	241	135	44	61
523	--TX	118	21	82	61
	--TX	118	21	82	61
	--TX	10	28	(180)	61
	--TX	10	28	(180)	61
524	--TX	329	19	94	61
	--TX	116	38	67	61
	--TX	137	67	51	61
	--TX	91	79	13	61
525	--TX	223	56	75	61
	--TX	361	86	76	61
	--TX	219	123	44	61
	--TX	250	36	86	61
	--TX	120	66	45	61
526	--TX	84	82	2	61
	--TX	48	112	(133)	61
	--TX	112	66	41	61
	--TX	252	30	88	61
	--TX	143	125	13	61
527	--TX	191	55	71	61
	--TX	--	48	--	61

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
528	--TX	312	67	79	61
	--TX	171	139	19	61
	--TX	--	0	--	61
	--TX	--	117	--	61
	--TX	102	--	--	61
	--TX	53	41	23	61
529	--TX	124	97	22	61
	--TX	36	26	28	61
	--TX	84	168	(100)	61
	--TX	63	--	--	61
	--TX	--	71	--	61
530	--TX	184	73	60	61
	--TX	--	131	--	61
	--TX	104	26	75	61
531	--TX	--	85	--	61
	--TX	--	55	--	16
	--TX	--	51	--	16
	--TX	114	18	84	16
538	--CO	172	31	82	62
539	--CO	50	33	34	62
540	--CO	251	43	83	62
541	--CO	232	28	88	62
542	--CO	177	19	89	62

LEGEND

(c) = filtered before analysis
(ND)= not domestic - includes industrial wastes
( ) = negative number
Units are in mg/l

TABLE 10

TOTAL NITROGEN REDUCTION IN ARTIFICIALLY AERATED LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
40	--IA #1	190	133	30	63
41	--IA #2	133	123	7.5	63
94	--OK	32.6	14.8	55	80
95	--OR	27.9	29.8	6.8	85
100	--WA	47.5	44.2	7.0	86
522	--TX	--	285	--	61
	--TX	--	300	--	61
	--TX	--	344	--	61
523	--TX	--	14	--	61
	--TX	--	14	--	61
	--TX	--	21	--	61
	--TX	--	21	--	61
524	--TX	--	111	--	61
	--TX	--	165	--	61
	--TX	--	239	--	61
	--TX	--	122	--	61
525	--TX	--	374	--	61
	--TX	--	344	--	61
	--TX	--	359	--	61
	--TX	--	319	--	61
	--TX	--	279	--	61
526	--TX	--	82	--	61
	--TX	--	104	--	61
	--TX	--	170	--	61
	--TX	--	180	--	61
	--TX	--	193	--	61
527	--TX	--	342	--	61
	--TX	--	244	--	61
528	--TX	--	131	--	61
	--TX	--	94	--	61
	--TX	--	140	--	61
	--TX	--	140	--	61
	--TX	--	118	--	61
	--TX	--	24	--	61
529	--TX	--	310	--	61
	--TX	--	114	--	61
	--TX	--	319	--	61
	--TX	--	124	--	61
	--TX	--	67	--	61

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
530	--TX	--	214	--	61
	--TX	--	13	--	61
	--TX	--	29	--	61
531	--TX	--	38	--	61
	--TX	--	119	--	61
	--TX	--	169	--	61
	--TX	--	164	--	61

TABLE 11

TOTAL PHOSPHATE (PO_4) REDUCTION IN ARTIFICIALLY AERATED LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
40	--IA #1	75	59	21.3	63
41	--IA #2	59	55	6.8	63
94	--OK	13.4	9.5	29	80
95	--OR	32.1	22.8	29	85
100	--WA	25.6	23.3	9	86
522	--TX	--	0	--	61
	--TX	--	0	--	61
	--TX	--	2	--	61
523	--TX	--	70	--	61
	--TX	--	70	--	61
	--TX	--	24	--	61
	--TX	--	24	--	61
524	--TX	--	840	--	61
	--TX	--	430	--	61
	--TX	--	390	--	61
	--TX	--	395	--	61
525	--TX	--	370	--	61
	--TX	--	300	--	61
	--TX	--	350	--	61
	--TX	--	250	--	61
	--TX	--	300	--	61
526	--TX	--	650	--	61
	--TX	--	350	--	61
	--TX	--	240	--	61
	--TX	--	180	--	61
	--TX	--	400	--	61
527	--TX	--	400	--	61
	--TX	--	280	--	61
528	--TX	--	290	--	61
	--TX	--	210	--	61
	--TX	--	220	--	61
	--TX	--	300	--	61
	--TX	--	280	--	61
	--TX	--	270	--	61

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
529	--TX	--	140	--	61
	--TX	--	155	--	61
	--TX	--	550	--	61
	--TX	--	320	--	61
	--TX	--	205	--	61
530	--TX	--	265	--	61
	--TX	--	110	--	61
	--TX	--	130	--	61
531	--TX	--	170	--	61
	--TX	--	400	--	61
	--TX	--	455	--	61
	--TX	--	470	--	61
538	--CO	23	3.3		62
539	--CO	3	30	--	62
540	--CO	3	30	--	62
541	--CO	3	2.1	--	62
542	--CO	240	30	--	62

TABLE 12

BIOCHEMICAL OXYGEN DEMAND (BOD) REDUCTION IN TERTIARY OXIDATION LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
19	--CA	14	7(C)	50.0	74
20	--CA	7	3(C)	57.1	74
22	--CA	9	11(C)	(22.2)	74
24	--CA #1	25	29	(16.0)	70
25	--CA #4	3.5	6	(71.0)	70
29	--CA	340	96	72.0	71
37	--IL #2	32.2	23.3	27.6	76
38	--IL #3	23.3	19.3	17.2	76
42	--KS	18	8	60	23
43	--KS	21.9	11.6	47	23
64	--MO #2	50	26	48	56
65	--MO #6	--	30	--	56
70	--NC #1	41	26	37	73
71	--NC #2	26	25	4	73
72	--NC #3	25	20	20	73
73	--NC #4	20	21	(5)	73
74	--NC #5	21	19	10	73
85	--OK #1	--	22	--	80
96	--OR	45	22	51	85
101	--WA	196(ND)	182(ND)	7	86
102	--WI	17.6	19.1	(8)	81
105	--ONT	14.6	9.2	34	68

LEGEND

(c) = filtered before analysis
(ND)= not domestic - includes industrial wastes
( ) = negative number
Units are in mg/l

TABLE 13

CHEMICAL OXYGEN DEMAND (COD) REDUCTION IN TERTIARY OXIDATION LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
29	--CA	660	575	12.9	71
43	--KS	153.2	144	6	23
85	--OK	--	142	--	80
101	--WA	580	550	5	86

TABLE 14

SUSPENDED SOLIDS REDUCTION IN TERTIARY OXIDATION LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
19	--CA	90	70(C)	22.2	74
20	--CA	70	6(C)	91.4	74
22	--CA	52	34	34.6	74
24	--CA #1	62	69	(11.0)	70
25	--CA #4	8.6	13	(51.0)	70
42	--KS	20	9	55	77
43	--KS	24.3	28.2	16	65
70	--NC #1	66	60	13	72
71	--NC #2	60	57	5	72
72	--NC #3	57	45	21	72
73	--NC #4	45	50	(11)	72
74	--NC #5	50	46	8	72
85	--OK #1	--	28	--	80
96	--OR	52	45	13.5	85
101	--WA	580(ND)	520(ND)	10	86
102	--WI	--	42	--	81
105	--ONT	45.0	11.0	76	68

LEGEND

(c) = filtered before analysis
(ND)= not domestic - includes industrial wastes
( ) = negative number
Units are in mg/l

TABLE 15

TOTAL NITROGEN REDUCTION IN TERTIARY OXIDATION LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
22	--CA	12.7	5.5(C)	56.7	74
25	--CA #1	30.5	29.1	4.0	70
29	--CA	18.1	25.9	(43.1)	71
43	--KS	26.3	30.2	(15.0)	65
64	--MO #2	10.8	4.8	55.6	56
65	--MO #6	--	6.1	--	56
85	--OK	--	15.5	--	80
96	--OR	29.8	25.2	15.5	85
101	--WA	44.2 ND)	39.4(ND)	11	86
102	--WI	--	11.3	--	81
105	--ONT	21.0	23.9	(14)	68

LEGEND

(c) = filtered before analysis
(ND)= not domestic - includes industrial wastes
( ) = negative number
Units are in mg/l

TABLE 16

TOTAL PHOSPHATE (PO_4) REDUCTION IN TERTIARY OXIDATION LAGOONS

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
22	--CA	18.1	8.1	55.2	74
25	--CA	25	30	(20.0)	70
29	--CA	16.3	17.1	(4.9)	71
37	--IL #2	10.4	3.6	65.4	76
38	--IL #3	3.6	3.1	13.9	76
43	--KS	28.7	25.0	13.0	65
64	--MO #2	8.0	3.2	60.0	56
65	--MO #6	--	4.6	--	56
85	--OK #1	--	10.0	--	80
96	--OR	22.8	21.9	3.9	85
101	--WA	23.3	21.7 (ND)	7	86
105	--ONT	12.6	14.1	(12)	68

LEGEND

(ND)= not domestic - includes industrial wastes
( ) = negative number
Units are in mg/l

TABLE 17

BIOCHEMICAL OXYGEN DEMAND (BOD) REDUCTION IN OXIDATION DITCHES

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
111	--AL	283	27	90	91
112	--OR	171	14	92	92
113	--SAS	245	23	91	92
114	--ME	294	25	92	92
115	--MN	330	20	93	93
116	--BC	311	19	94	93
117	--KS	645	38	94	93
118	--OH	241	13	95	94
512	--TX	--	85	--	61
	--TX	--	65	--	61
	--TX	345	5	99	61
513	--TX	999	430	57	61
	--TX	440	480	(9)	61
514	--TX	210	60	71	61
515	--TX	360	90	75	61
	--TX	40	50	(25)	61
	--TX	600	45	93	61
516	--TX	265	25	91	61
	--TX	--	17	--	61
	--TX	190	30	84	61
517	--TX	--	45	--	61
	--TX	165	90	45	61
	--TX	230	24	90	61
	--TX	400	40	90	61
	--TX	210	85	60	61
	--TX	230	7	97	61
518	--TX	160	115	28	61
	--TX	--	160	--	61
	--TX	--	30	--	61
	--TX	120	85	29	61
519	--TX	250	80	68	61
	--TX	195	25	87	61
	--TX	200	25	88	61
	--TX	--	80	--	61
	--TX	80	18	78	61

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
520	--TX	85	45	47	61
	--TX	20	9	55	61
	--TX	260	90	65	61
	--TX	85	90	(6)	61
	--TX	260	50	81	61
	--TX	--	5	--	61
521	--TX	100	13	87	61
	--TX	--	140	--	61
	--TX	--	23	--	61
	--TX	140	10	93	61
	--TX	--	4	--	61
543	--CO	191	26	86	62
	--CO	146	7	95	62
	--CO	230	3	99	62
544	--CO	146	7	95	62
545	--CO	230	3	99	62

LEGEND

( ) = negative number
Units are in mg/l

TABLE 18

SUSPENDED SOLIDS REDUCTION IN OXIDATION DITCHES

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
115	--MN	337	37	89	93
116	--BC	186	12	94	93
118	--OH	307	34	89	94
512	--TX	--	119	--	61
	--TX	--	65	--	61
	--TX	147	14	91	61
513	--TX	999	180	82	61
	--TX	375	217	42	61
514	--TX	118	341	(189)	61
515	--TX	999	151	85	61
	--TX	43	116	(170)	61
	--TX	450	81	82	61
516	--TX	101	55	46	61
	--TX	--	26	--	61
	--TX	134	28	79	61
517	--TX	--	37	--	61
	--TX	92	53	42	61
	--TX	239	31	87	61
	--TX	381	34	91	61
	--TX	117	95	19	61
	--TX	287	10	94	61
518	--TX	113	76	33	61
	--TX	--	124	--	61
	--TX	--	28	--	61
	--TX	67	34	49	61
519	--TX	260	55	79	61
	--TX	92	12	87	61
	--TX	80	12	85	61
	--TX	--	60	--	61
	--TX	53	18	66	61
520	--TX	60	44	27	61
	--TX	35	49	(40)	61
	--TX	184	32	83	61
	--TX	69	85	(23)	61
	--TX	251	14	94	61
	--TX	--	17	--	61

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
521	--TX	108	24	78	61
	--TX	--	190	--	61
	--TX	--	35	--	61
	--TX	146	10	93	61
	--TX	--	--	--	61
543	--CO	161	68	58	62
544	--CO	151	15	90	62
545	--CO	329	19	94	62

LEGEND

( ) = negative number
Units are in mg/l

TABLE 19

TOTAL NITROGEN REDUCTION IN OXIDATION DITCHES

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
115	--MN	23.9	15.8	34	93
512	--TX	--	302	--	61
	--TX	--	332	--	61
	--TX	--	14	--	61
513	--TX	--	442	--	61
	--TX	--	485	--	61
514	--TX	--	32	--	61
515	--TX	--	562	--	61
	--TX	--	247	--	61
	--TX	--	485	--	61
516	--TX	--	78	--	61
	--TX	--	36	--	61
	--TX	--	154	--	61
517	--TX	--	114	--	61
	--TX	--	222	--	61
	--TX	--	169	--	61
	--TX	--	146	--	61
	--TX	--	146	--	61
	--TX	--	129	--	61
518	--TX	--	350	--	61
	--TX	--	294	--	61
	--TX	--	304	--	61
	--TX	--	273	--	61
519	--TX	--	175	--	61
	--TX	--	60	--	61
	--TX	--	174	--	61
	--TX	--	239	--	61
	--TX	--	128	--	61
520	--TX	--	234	--	61
	--TX	--	75	--	61
	--TX	--	22	--	61
	--TX	--	304	--	61
	--TX	--	391	--	61
	--TX	--	80	--	61
521	--TX	--	282	--	61
	--TX	--	247	--	61
	--TX	--	304	--	61
	--TX	--	34	--	61
	--TX	--	14	--	61

TABLE 20

TOTAL PHOSPHATE (PO_4) REDUCTION IN OXIDATION DITCHES

CASE	LOCATION	INFLUENT	EFFLUENT	% REMOVAL	REFERENCE
512	--TX	--	540	--	61
	--TX	--	530	--	61
	--TX	--	420	--	61
513	--TX	--	0	--	61
	--TX	--	0	--	61
514	--TX	--	0	--	61
515	--TX	--	0	--	61
	--TX	--	0	--	61
	--TX	--	360	--	61
516	--TX	--	220	--	61
	--TX	--	440	--	61
	--TX	--	530	--	61
517	--TX	--	280	--	61
	--TX	--	310	--	61
	--TX	--	450	--	61
	--TX	--	180	--	61
	--TX	--	370	--	61
	--TX	--	630	--	61
518	--TX	--	410	--	61
	--TX	--	245	--	61
	--TX	--	360	--	61
519	--TX	--	250	--	61
	--TX	--	92	--	61
	--TX	--	150	--	61
	--TX	--	200	--	61
	--TX	--	213	--	61
520	--TX	--	80	--	61
	--TX	--	150	--	61
	--TX	--	365	--	61
	--TX	--	160	--	61
	--TX	--	280	--	61
	--TX	--	340	--	61
521	--TX	--	250	--	61
	--TX	--	200	--	61
	--TX	--	390	--	61
	--TX	--	195	--	61
	--TX	--	380	--	61

TABLE 21

FECAL COLIFORM REDUCTION IN OXIDATION DITCHES

CASE	LOCATION	INFLUENT mpn/100 ml	EFFLUENT mpn/100 ml	% REMOVAL	REFERENCE
543	--CO	3×10^6	3×10^2		62
544	--CO	7×10^6	79×10^3		62
545	--CO	27.8×10^6	17.2×10^3		62

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APPENDIX C

PROJECT STUDY DESIGN

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PROJECT STUDY DESIGN

The approach chosen by RETA to accomplish the study objectives is based upon refined objectives, specific scope, and engineering logic. FWQA input will be formally solicited at the beginning of the project as well as for the final project report. Continual informal dialogue between FWQA and RETA is encouraged during the study.

An initial study design has been developed as illustrated in Figure I-1. This study design will become active with the review and incorporation of FWQA recommendations following the expected project orientation and review conference. The project has been separated into 33 Tasks and the information available to the Project Manager divided into detail sub-tasks. For the purpose of orientation, brief comments are provided at the task level breakdown. Additional information will be available to FWQA as the project is explained and reviewed in conference.

The required information will be obtained by utilizing existing data and identifying additional data sources. Following evaluation and condensation of this data, a critique of lagoon technology will be made by RETA engineers, and conclusions and recommendations formulated.

The following task narrative is keyed to Figure I-1 illustrating the logic and the interrelationship between tasks.

Task #1 - Establish Objective

Establish objective of study internally, explicitly with mutual agreement of FWQA.

Task #2 - Establish Scope

Establish scope with FWQA of study to specifically limit this study to allow in depth amplification of investigations leading to the accomplishment of the stated objectives.

Task #3 - Develop Time Budget

Consider and schedule time budgets for personnel to adequately staff the study and satisfy RETA and FWQA officers of project completion.

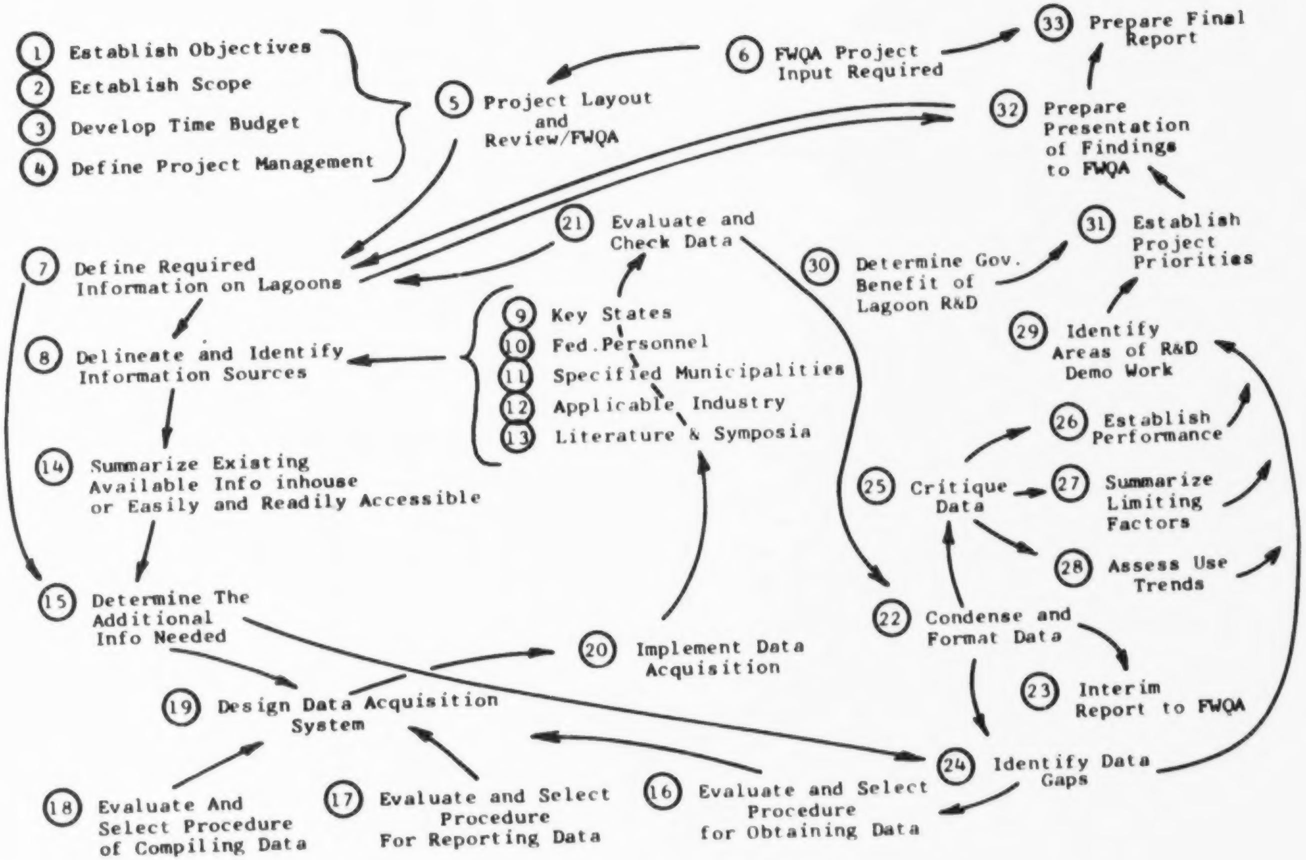
① Establish Objectives
② Establish Scope
③ Develop Time Budget
④ Define Project Management
⑤ Project Layout and Review/FWQA
⑥ FWQA Project Input Required
⑦ Define Required Information on Lagoons
⑧ Delineate and Identify Information Sources
⑨ Key States
⑩ Fed. Personnel
⑪ Specified Municipalities
⑫ Applicable Industry
⑬ Literature & Symposia
⑭ Summarize Existing Available Info inhouse or Easily and Readily Accessible
⑮ Determine The Additional Info Needed
⑯ Evaluate and Select Procedure for Obtaining Data
⑰ Evaluate and Select Procedure For Reporting Data
⑱ Evaluate And Select Procedure of Compiling Data
⑲ Design Data Acquisition System
⑳ Implement Data Acquisition
㉑ Evaluate and Check Data
㉒ Condense and Format Data
㉓ Interim Report to FWQA
㉔ Identify Data Gaps
㉕ Critique Data
㉖ Establish Performance
㉗ Summarize Limiting Factors
㉘ Assess Use Trends
㉙ Identify Areas of R&D Demo Work
㉚ Determine Gov. Benefit of Lagoon R&D
㉛ Establish Project Priorities
㉜ Prepare Presentation of Findings to FWQA
㉝ Prepare Final Report

FIGURE I-1 TASK NETWORK DIAGRAM

Task #4 - Define Project Management

Define with RETA and verify with FWQA that the project management will have responsibilities and names attached internally and externally. Progress report format, frequency and extent will be established with FWQA. Format for the final report will be mutually developed.

Task #5 - Project Layout and Review with FWQA

The total project will be designed and discussed as laid out in the Task Network Diagram with full compliance and/or modification by FWQA. The material developed in the first five tasks will be presented in conference to FWQA.

(1) Tasks will be written up
(2) Times will be estimated
(3) Project will be illustrated

Task #6 - FWQA Project Input Required

Input on the project will be formally sought during Tasks #5 and #33. It is to be understood that input and correspondence from the designated FWQA project officer will be encouraged throughout the project. Formal changes and recommendations will be entertained during the project layout and preparation of final report.

Task #7 - Define Required Information on Lagoons

Activities in this task will be directed to identifying specific questions to satisfy the project objectives, such as:

How many lagoons are in existence?

Where are the majority of the lagoons located?

By whom were the lagoons designed?

What agencies were responsible for the approval of the lagoons?

What problems have arisen?

What designs have been used?

What effect does geography have?

What parameters have been used for operating and design?

What efficiencies have been found?

What is or can be done to improve the efficiencies?

What are common advantages and disadvantages of lagoons?

What costs are common and where were these found?

Where are lagoons most common and why?

What are the seasonal effects on the efficiency of lagoons?

How much capital has been invested in lagoon systems at the local, state, Federal, as well as international level?

What are the aesthetic descriptive parameters?

Is a lagoon a secondary treatment system? If so, why?

Task #8 - Delineate and Identify the Information Sources Relative to Who, What, Where, When and Why

As illustrated in the Task Network Diagram, Task #9 through Task #13 indicating key states, Federal personnel, specified municipalities, applicable industry, and literature and symposia will be established as specifically as possible to simplify procedures of developing the necessary information. The result of this task will be the identification of personnel which should be able to supply information, as well as the location and identification of information specifically aimed at satisfying the objectives of this study. Typical information which should be developed during this task would be as follows:

(1) Who specifically are the key people using lagoons?

  a. Local
  b. State
  c. Federal
  d. International

(2) What controlling factors have caused these uses?

  a. Dollars
  b. Time
  c. Efficiency
  d. Temporary treatment necessary

(3) Where are the majority of lagoons of several different types of efficiencies?

  a. Missouri
  b. California
  c. Texas
  d. Florida
  e. Indiana
  f. Michigan
  g. Mississippi
  h. Other

(4) When were most lagoons built and what is the present construction rate?

(5) Why are states and individuals using lagoons?

(6) What data is available and in what form and assessibility is it, such as influent-effluent criteria on

  a. BOD
  b. Settleable Solids
  c. Suspended Solids
  d. Flotables
  e. COD
  f. Phosphorus
  g. Nitrogen

h. Algae
i. Coliform

(7) What aesthetic parameters are important and to what extent are they, such as

a. Odor
b. Insects
c. Lataral growth
d. Nutrient enrichment of rivers and lakes
e. Appearance

Task #9 - Key States to be Considered

The purpose of this task is to develop criteria for the selection of states and to develop the skeletal framework upon which Task #20 - Implementation of Data Acquisition may be made. Information which should compose the basis of the skeletal framework would include the following:

(1) Number of lagoons used

(2) Present opinion by state officials

a. Favorable
b. Unfavorable

(3) Personnel and regulatory body which will co-operate with project management and the objectives of this study

(4) Geographical uniqueness or representation illustrated by the State

(5) Accessibility of data required

(6) To whom are lagoon permits issued and why or why not are they issued

(7) Receiving water characteristic data availability

Task #10 - Federal Personnel

The purpose of this task is to identify those personnel within the Federal structure whose activities would lend meaningful information to the technology of lagoons. Selection of these personnel which will be utilized during Task #20 - Implementation of Data Acquisition will be based upon

(1) Experience

(2) Data availability and reliability

(3) Evaluation of future trends and uses

   a. Problems
   b. Advantages

Task #11 - Selection of Specified Municipalities

The activities in developing the skeletal framework during this task will be concerned with identifying municipalities experienced in the use of lagoons for waste treatment. Those cities identified will be utilized during the Task #20 - Implementation of Data Acquisition to supply operational data for the assessment of lagoon technology. Criteria used in the selection of the municipalities will be as follows:

(1) Reason for municipality using lagoons

(2) Satisfaction or dissatisfaction with the operation of the lagoons

(3) Performance data availability

(4) Problems experienced during the operation of lagoons as specified by

   a. Parameters
   b. Aesthetic considerations

(5) Relation of municipality with regulatory body indicating the degree of severity of any problems of effluent discharge from lagoons

(6) Has the operation of the lagoons been satisfactory to the point that the municipality will build more lagoons. Why or why not?

(7) Geographic and population uniqueness and representation will be considered.

Task #12 - Applicable Industrial Uses of Lagoons

Activities in this task will be directed to establishing the skeletal framework of industrial data which applies directly to the objectives of this study. Typical questions and information which will be required is as follows:

(1) Why would industry use lagoons?

(2) Availability of data for publication and evaluation

(3) Geographic uniqueness or representation

(4) Receiving water characteristics

(5) Relationship of the industry with the concerned regulatory agencies

(6) Will other lagoons be built? Why or why not?

(7) Note industries particularly fond of lagoons and those who have found them unsatisfactory and why.

Task #13 - Literature and Symposia Used to Seek Experience of Others such as Consultants and Academicians

Efforts will be spent during this task phase to update the literature in the comprehensive files of RETA as well as take advantage of conferences where experts in the area can be gathered to describe developments and technology on lagoons. Efforts will be expended in this task on an intermittent basis thereby providing the latest information available for the preparation of the final report. Specific duties which will be covered in this task area are as follows:

(1) Utilizing existing files, RETA personnel assigned to this project will become intimately familiar with the literature

(2) Use of information gathering services will be considered to broaden the spectrum of literature covered

(3) These data gathered from the literature will be reviewed and critiqued with the study objectives in mind to fulfill the requirements of Task #8 - Delineating and Identifying Information Sources

(4) Advantage will be taken of conferences and symposia which will be held during the span of this project to economically discuss the current status of lagoon technology with as many experts as feasible

(5) Specific individuals will be selected and visited to obtain data and opinions on the use and effectiveness and expected trends in lagoon technology.

Task #14 - Summarize Existing Available Information In-House or Easily and Readily Accessible

This task has been designed to bring together that information which was easily obtained during the development of Task #8, #13. Considerable information is expected to be brought to the surface based on in-house files and from initial contacts establishing the skeletal framework for the implementation of data acquisition. This summary will not represent the final format or content of the data gathered but should specify existing readily available reliable data. The summary should reflect tabulation of information delineated in Task #8 plus data on influent and effluent parameters.

Task #15 - Determine the Additional Information Needed

The required information was defined in Task #7 and that information which is readily available was summarized into the existing information in Task #14. The primary emphasis during this activity will be the comparison of these two sources of information, thereby identifying the additional information which is needed. The additional information will be specified exactly as to the type and extent of data which is required. The additional information needed will, to a degree, affect Task #19 which involves the design of the data acquisition system.

Task #16 - Evaluate and Select Procedure for Obtaining Data

Of the several methods available such as using questionnaires, personal interviews, telephone conversations, group seminars, and others, procedures will be evaluated and one selected for securing the additional information needed. The advantages and disadvantages of each procedure considered will be noted and the procedures selected will satisfy at least the following requirements:

(1) Minimum requirement of RETA personnel

(2) Little or no clearance required by Federal government

(3) Minimal effort required by individual possessing the information

(4) Require the minimum time of the interviewer and interviewee or other situations for responding to the request for information

(5) Information must be obtained within the budget allotted.

Task #17 - Evaluate and Select Procedure for Recording Data

The activities to be undertaken during this task will involve consideration of alternative methods of recording and reporting the information accumulated. Considerations which will play an important role in selecting a procedure for recording the data will involve at least the following:

(1) The procedure must consider minimum time requirement

(2) The procedure should reduce the opportunity for data transcribing errors

(3) Under field conditions, the data reporting system should be uncumbersome to handle

(4) The data reporting system should not impose on the participant

Alternatives available for consideration in reporting the data may be systems such as the following:

(1) Use of designed forms or questionnaires

(2) Use of portable tape recorders under interviewing situations

(3) Use of Polaroid close-up cameras for documents

(4) Use of IBM field punch cards system

Task #18 - Evaluate and Select Procedures of Compiling Data

Primarily the activities undertaken under this task will be concerned with noting various systems of compiling data of the type which was defined under Task #7. Considerations will be made of systems which do the following:

(1) Minimize the actual data handling time

(2) Require the minimum amount of engineering interpretations

(3) Create the smallest typing load

(4) Produce the data in the clearest and most logical order

(5) Provide cross index information retrieval of the several systems available or that may be designed

Systems such as the following may be considered:

(1) Use of standard interview or question forms which may be Xeroxed and cross referenced

(2) Transfer of information from several sources and forms onto computer data retrieval systems

(3) Use of key point card index filing systems

(4) Use of microfilm data retrieval systems

(5) Division of data retrieval among several RETA employees, thereby making each completely responsible for a certain segment or segments of the data base

Task #19 - Design Data Acquisition System

Using the input from the additional information defined in Task #15 and the systems which have been evaluated during Tasks #16 through #18 for obtaining, reporting and compiling data,the actual acquisition system will be designed. The completion of this task will render a clear path of who will be contacted with specific identification, what will be required of this individual, in what form it will be reported, and what will be done with the data once obtained. The data acquisition systems will be developed taking into account the differences and municipal, Federal, and industrial information sources and any necessary time delays which may be anticipated.

Task #20 - Implement Data Acquisition

This task will require personnel to secure the necessary information. As illustrated in the Task Network Diagram, the data will be required using the skeletal framework established in Tasks #9, #10, #11, #12 and #13 to provide the necessary data base to evaluate the technology of lagoons. Efforts of personnel working in this task area will deal with implementing the procedures, evaluating and selected Tasks #16, #17, and #18 for the total acquisition system. RETA personnel engaged in this activity will know exactly what information should be obtained from whom and how it it should be reported and compiled. Some flexibility in this is anticipated, due to differences in agencies and the availability of data in different states.

Task #21 - Evaluate and Check Data

As indicated in the Task Network Diagram, the data will be evaluated by the project manager or engineer and a check will be made to determine if in actuality the required information on lagoons has been obtained. If the required information has not been obtained, additional efforts will be made to determine the additional information needed and to take steps to obtain this information or identify the information as a data gap as illustrated in Task #24.

Task #22 - Condense and Format Data

The data which has been compiled will be condensed using any applicable statistical tools and formats established which will be utilized in Task #23 and throughout the rest of the study. The format defined for the data will be designed to provide information in a tabular form indicating its accuracy, source, special conditions under which it was taken, and where possible, the reference to other supportive or non-supportive related data acquired by other agencies.

Task #23 - Interim Report to FWQA

Primarily this task will concern activities dealing with the production of an interim report which will utilize the condensed and formated data thereby enabling FWQA to utilize the available data at the earliest possible time This interim report will have little or no effect on the conclusions or recommendations but will indicate the reliability and depth to which the spectrum of data should be representative.

Task #24 - Identify Data Gaps

As indicated in the Task Network Diagram, input from Task #22 indicating the data in the condensed form, as well as the additional data which was determined necessary in Task #15, when combined, generate the necessity for again examining if there is a possible means of obtaining the data as in Task #16. With this positive check, efforts may be made to obtain this data identified as missing or if determined not feasible, these data gaps identified will be utilized in Task #29 of the study. The result of the efforts in this task will deal specifically with identifying the areas in which the data was found inadequate and illustrating the reasons of inadequacy.

Task #25 - Critique Data

Considerable engineering evaluation will be spent during this task to interpret the meaning of the data which has been developed during the study. The data critique will involve pointing out and discussing the relative strength and weaknesses of the lagoon system as have been observed during the study. Inadequacies of the data will be discussed noting limitations of personnel and funds, and awareness of the importance of maintaining reliable and accurate records. During this critiquing task, the basis for Tasks #26, #27, and #28 will be established to explore in more detail the lagoon performance, limiting factors, and expected trends. The information developed under Task #25 will be utilized in the preparation of a small chapter in the final report.

Task #26 - Establish Performance

Considerable effort will be devoted to identifying the performance of lagoons as functions of various factors, such as geography and hydraulic and organic overloading in light of the water quality criteria and effluent quality standards which have been developed by the several states under study. This task will require efforts to satisfy the objectives of the study indicating the adequacy of the lagoons, the current thinking of the various states.

Task #27 - Summarize Limiting Factors

The effort here is to be primarily directed at specifying the limiting factors which have been observed in the several geographic areas under the various conditions and operations to make effective the operation of lagoons. The information developed and discussed here will be based upon the critique developed in Task #25, and should satisfy the objectives of the study indicating the problems and limiting factors of lagoons.

Task #28 - Assess Use Trends

Activities in this task will be directed to achieving the objectives of this study by indicating the guidelines and the future extent and use of the lagoons. Information developed in the critique in Task #25 will be utilized and amplified to indicate why states are encouraging or discouraging the use of lagoons. Efforts will be made to assess the number of units expected, the various regions, and to identify any problems which are expected and procedures which have been created to handle them or justification to tolerate them.

Task #29 - Identification of Areas of R & D and Demonstration Work

Information developed during Tasks #26, #27, #28, and #24 indicating the performance, limiting factors, trends and information gaps will be utilized to identify the areas where research or demonstration work using lagoons is required. The activities in this task will be directed to specifically noted projects which, if carried out under sufficiently large scale over a sufficiently long period of time, would materially advance the state of technology of lagoons. The areas of R & D and demonstration work may cover such items as:

(1) Reevaluation of design criteria

(2) Development of operator guidelines

(3) Incorporation of certain mechanical devices

(4) Use of chemicals for upgrading performance

(5) Converting the lagoons economically to another unit operation

(6) Identification of the economic alternatives and advantages or disadvantages of lagoons illustrating the cost per measure of organic pollutant per increment of time

Task #30 - Determine Governmental Benefit of Lagoon R & D

An effort will be made to clarify any substantial benefit that additional money spent on reasearch and development for lagoon technology would accrue to the government. Typical information developed here would be identification of the total governmental expense involved in the capital investment facilities in lagoon operations. Another aspect will be the identification of the time delay required for the construction of elaborate treatment facilities versus modification or upgrading of lagoon systems.

Task #31 - Establish Project Priorities

The input from Task #29, identification of the areas of R & D work or demonstration projects, plus the input of Task #30 which determines the benefit of a government for supporting these works will be utilized to establish a rank priority of projects which will substantially upgrade the lagoon technology. The results of this effort will be a tabular indication with sufficient justification of the projects with a relative time base of urgency identified. The information will be prepared in such a manner that the FWQA would be in a position to make a policy decision on sponsoring these types of projects.

Task #32 - Prepare Presentation of Findings to FWQA

As illustrated in Task Network Diagram, the findings will be prepared for a conference with FWQA prior to the preparation of the final report. The project manager will be responsible for making a positive check to insure that the defined information which was required in Task #7 has been obtained or identified as missing and so accounted for. Sufficient tables, figures, and graphic materials for conference presentation will be prepared to provide FWQA with a full appreciation of what the contents of the final report will be.

Task #33 - Prepare Final Report

As noted on the Task Network Diagram, FWQA input will be required following the presentation of findings as the final report is being prepared. The report format will be that as agreed upon in Task #4 and will be delivered with the required number of copies as specified in the contract agreement.

APPENDIX D

EVALUATION OF LAGOON TREATMENT ON A STATE-BY-STATE BASIS

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APPENDIX D

EVALUATION OF LAGOON TREATMENT ON A STATE-BY-STATE BASIS

The following state-by-state descriptions of lagoon performance are the result of conversations and visits with state engineers, officials from agencies concerned with water quality and wastewater treatment, and other experts in the field. The attitudes of state officials towards the use of lagoons for wastewater treatment were determined and an evaluation completed of various performance problems, conditions affecting performance, monitoring and recording of data, design criteria, and existing and recommended state programs.

The states have been divided into nine geographic regions, shown in Table 1.

SOUTHWEST REGION

Geographically, there are several distinct situations in this region. Climatically, all of the states have common features especially with regard to altitude. Arizona has the most uniformly amenable climate: the hot, dry environment produces little effluent, and, in many cases, effluents are reused for irrigation.

California, on the other hand, has a variety of climates ranging from low, hot desert interior to cloud-covered, wet, coastal areas. Areas to the west of the mountains are covered by clouds for considerable parts of the year, and lagoon performance suffers. In areas of heavy flow volume and relatively poor evaporation, effluent enters receiving streams and ultimately coastal estuarine areas, where the accumulation of algae laden effluent creates problems of oxygen depletion. As previously stated, a greater variety of facilities have been tried in California than in any other state. Although some facilities appear to perform very well, the heavy production of algae, short-circuiting and the inability to effectively remove nutrients makes use of lagoons throughout this state questionable.

ARIZONA - In Arizona lagoon performance is considered an acceptable process for secondary treatment; there are plans to construct more lagoons as required.

TABLE 1

STATES CATEGORIZED BY REGION

MIDDLE ATLANTIC

- Delaware
- Maryland
- North Carolina
- South Carolina
- Virginia

MISSOURI BASIN

- Missouri
- Montana
- Nebraska
- North Dakota
- South Dakota

GREAT LAKES

- Illinois
- Iowa
- Michigan
- Minnesota
- Wisconsin

NORTHWEST

- Idaho
- Oregon
- Washington

NORTHEAST

- Connecticut
- Maine
- Massachusetts
- New Hampshire
- New Jersey
- New York
- Rhode Island
- Vermont

OHIO BASIN

- Indiana
- Kentucky
- Ohio
- Pennsylvania
- West Virginia

SOUTH CENTRAL

- Arkansas
- Colorado
- Kansas
- Louisiana
- New Mexico
- Oklahoma
- Texas

SOUTHWEST

- Arizona
- California
- Nevada
- Utah

SOUTHEAST

- Alabama
- Florida
- Georgia
- Mississippi
- Tennessee

Economic considerations are the main reason for construction of lagoons. Climate is amenable to their operation and the major portion of the effluent is utilized for irrigation. For these reasons, operating records are not required although a daily log is recommended.

No discharges of any secondary facility are permitted into waters where nutrient enrichment would create problems.

Some operating figures do show a rather poor BOD and SS removal; many of the facilities may be overloaded due to rapid population expansion. In any event, high evaporation and percolation rates leave relatively little effluent to be discharged.

CALIFORNIA - State engineers in California indicate only marginal satisfaction with lagoon performance. Researchers are working to refine and define lagoon performance. Lagoons are generally viewed as satisfactory for smaller communities or as interim facilities. Treatment by lagoon generally follows another type of treatment, with effluent loadings from the primary facility unknown. As a result, lagoon performance cannot be adequately verified.

Numerous studies have been conducted in California and their results indicate that lagoon performance often falls short of the degree of treatment required to protect the waterways.

NEVADA AND UTAH - Both states have very few aerobic lagoon installations.

Ten State Standards are generally followed in designing installations and periodic use mitigates against serious problems. Where continuous use might create problems, total containment is practiced. Winter operation in the northern part of both states or at high elevations does create some problems related to ice cover but these are not regarded as serious.

Sampling is of a periodic nature and the results, which show high BOD reduction and satisfactory coliform bacteria reduction. Chlorination is practiced where necessary to accomplish adequate disinfection.

SOUTH CENTRAL REGION

The states of the South Central Region are generally satisfied with lagoons. Favorable climatic conditions are probably the key to their relative success here.

While some states in this region give lagoons unqualified approval, others are more cautious. In a high evaporation state such as New Mexico, there is no problem with effluent discharge. Streams within the region must be viewed with caution. Louisiana apparently considers the general performance of lagoon effluent suitable.

At the present time, Arkansas, of the seven states in the region, probably has more information about the actual performance of their facilities than any other state reporting to the contractor. A system of periodic on-station checks and measurements leaves little doubt as to performance. In certain portions of this state lagooning is specifically prohibited in order to maintain high receiving water quality.

Algal discharge has become a serious problem in both Oklahoma and Texas.

TEXAS - Texas is trying a self-reporting system to gather operational data and assess the performance of lagoons. The operators are not required to run specific tests if, in their opinion, there is no need to do so. Consequently, significant gaps appear in the data. Conversion to a computerized audit of all state facilities should result in more meaningful data in the future.

Oxidation ponds or lagoons are considered adequate for treatment in rural areas, but the minimal maintenance requirement produces questionable performance.

Testing frequency is based on a graduated scale, depending upon size of the plant and flow delivered.

Serious problems have developed with regard to the presence of algae in effluents. No real assessment of the potential drainage to receiving streams has been accomplished at this time but presumably it may be great. Experiments are in progress to investigate the utilization of Daphnia as a means of removing algae, however, limited success has been achieved.

NEW MEXICO - Despite a sampling schedule of only once every two to three years, lagoons are considered quite adequate for the needs of the state.

Improvements suggested by state officials for solution of New Mexico's problems include concrete aprons for weed control and some means of operating lagoons in series of parallel, neither improvement is currently specified in State design requirements.

Low cost for small municipalities is cited as the dominant criteria for choosing lagoons.

COLORADO - Facultative lagoons, the predominant type, are monitored once a year for BOD_5. They generally are considered to achieve at least 80 percent BOD_5 reduction.

Chlorination is not normally required as total or fecal coliform shows a 90 to 95 percent reduction. Effluent coliform counts available reveal that this objective is met under most conditions; however, coliform counts still range from about 2,000 to 50,000 (MPN/100 ml).

Longer detention time is recommended by state engineers but since few coliform counts are made on individual lagoon operations, there are insufficient data to validate this report.

LOUISIANA - The attitude of Louisiana officials is typical of the philosophy that lagoons are designed to work by consulting engineering firms, these designs are approved by the State Department of Health and hence, lagoons do work. "Work" is defined as 85 percent BOD_5 removal and any other standards required to meet the water quality criteria for the receiving stream. State officials iterate that, "Since lagoons work (as designed) they do not require testing." Therefore, no regular testing is done. A voluntary training program is in effect with no mandatory certification law.

This state is satisfied with lagoons and presently plans construction of additional installations. Lagoons are inexpensive and reliable in outstate areas; they are not used in larger municipalities because of high land costs.

Two cell systems in series are specified; all indications would point to a degree of success with BOD, bacteria and suspended solids reduction other than algae removal.

Stream standards have been published for the state and are not generally as stringent as for more northern waters. Monthly median coliform counts of 1600/100 ml or 5000/100 ml for 10 percent of the time are allowable. Dissolved oxygen is required to be not less than 50 percent of possible saturation at existing stream temperatures at any time due to effluent. Two cell lagoons in series can probably accomplish this with relative ease in this southern location.

KANSAS - Kansas officials estimate more than 150 municipal lagoons with an additional 700 to 800 annual waste (feedlot) facilities, 50 to 100 industrial facilities, and in excess of 600 individual (private dwelling) lagoons of smaller size. The largest of the municipal plants is over 60 acres. (STORET lists 232 municipal lagoons).

Lagoons are regarded as equivalent secondary treatment in Kansas and additional design and construction is authorized in areas where population density permits.

It is felt that these facilities produce a relatively constant effluent, and no regular sampling program is required or implemented.

Since there are no clearwater streams in the state, the presence of algae in the effluent is not regarded as a significant problem.

The figures on percent BOD_5 reduction, shown in Table 2 appear to present a picture of total lagoon performance. However, they are, in themselves, somewhat misleading. System #1 (Overbrook, Kansas) under peak loading 9 a.m. to 3 p.m. produced a high BOD_5 reduction, 95 percent, and good effluent, 10 mg/l. The flow diminished during the period of 11 p.m. to 9 a.m., as did concentration of the wastewater 50 mg/l BOD_5. Under the influence of no light or photosynthesis, the effluent quality, while still quite acceptable (18 mg/l), produced only 64 percent BOD_5 reduction during this 10 hour period. Flow data was not available, so total load to the receiving stream could not be calculated. The cycle is repeated daily.

These data indicate one significant point: following a period of cloud cover, the 10-hour periods at night might produce a totally unacceptable effluent to the receiving stream, and due to the nature of sampling, would never be recorded. Also apparent is the possibility that much of the nutrient source remaining from the primary cell is converted to algal cells in the final cell, thereby creating the higher effluent BOD_5 and COD. This is not seen in

TABLE 2

LAGOON PERFORMANCE DATA IN KANSAS (60)

DATE & TIME PERIOD	INFLUENT BOD	I°*	% REMOVE	II°**
4-20, 9 am - 3 pm	170	10	95	17
4-20, 3 to 11 pm	110	14	87	17
4-21, 11 to 9 am	050	16	64	22
4-21, 9 to 3 pm	115	12	90	21
4-21, 3 to 11 pm	110	15	84	13
4-22, 11 to 9	032	11	66	17
4-22, 9 to 3	100	13	92	32
TC Total Coliform	52×10^6	215×10^3		6×10^3
5-5, 3 to 9	240	41		23
5-6, 9 to 7	135	32		26
5-6, 3	260	51		33
5-6, 3 to 10	185	45		31
5-7, 10 to 8	120	46		31
5-7, 8 to 3	205	55		45
5-7, 3 to 11	280	45		44
5-8, 10 to 4	230	38		39
5-11, 10 to 4	225	38		29
5-11, 4 to 10	320	27		35
TC Total Coliform	151×10^6	65×10^3		143

* primary cell
** secondary cell

System #2 where the II° pool shows a lower BOD than the I° cell.

The influence of increased detention time is dramatically demonstrated in total coliform counts. In Plant #1, with only 75 days detention time, there were still 6000 cells/100 ml in effluent where considerable water fluctuation was observed. Plant #2, on the other hand, with 130 days detention time produced only 143 cells/100 ml at the point where effluent could occur even though the initial concentration was almost three times as high. Losses from both seepage and evaporation kept the final cell in Plant #2 from producing an effluent.

The essentially poor quality of receiving streams and the use of effluent of the qualities shown for irrigation of land where available water is precious are both arguments for continued use of lagoons in this state.

OKLAHOMA - Oklahoma officials, unlike those in Kansas, are discouraging the construction of lagoon installations. There appears to be no justification for this attitude other than an apparent dislike for lagoons. Performance for those lagoons where data have been reported, appear to be neither better nor worse than other states which accept them as satisfactory treatment.

Over 400 lagoons presently in the state were constructed instead of conventional plants for obvious economic benefit. The state does not require sampling although state law does require that the operator take samples once or twice a month.

Many installations are two cell systems, apparently to improve performance. The results, unfortunately, indicate many of the plants have been severely overloaded in the first cell so that failure in the second or subsequent cell is virtually assured.

Algae in the effluent is regarded as a significant problem. Although not stated, it would appear that high effluent BOD_5 is partly responsible for furthering the growth of blue-green algae and subsequent complaints from downstream residents.

SOUTHEAST REGION

A large number of lagoons exist in this region and the reactions to them vary from almost complete acceptance through cautious use to total rejection of the concept of lagooning as a waste treatment process. The most adamant rejection is in those states where serious experimental observation has provided a data base to indicate the failure of lagoons under existing conditions.

This evaluation, as in other situations, is not to be taken as a blanket condemnation of lagoon treatment. It does, however, focus on the numerous operational difficulties which can accompany faulty design and maintenance, and a basically erroneous philosophy of wastewater treatment.

ALABAMA - While the covered responses averaged 90 percent plus BOD_5 reduction, STORET data for this state are meaningless; industrial and private lagoons, which require prior approval, are not usually listed by acreage or type. Standard measurements of flow, BOD and SS are required of all municipal facilities, including lagoons. Because of the level of operator training, no effluent data is required of either lagoons or small treatment plants.

State officials feel that most serious problems ultimately reflect on the quality of maintenance; specific problems are poor dike management and erosion, marginal and floating vegetation, blue-green algae, and grease build-up in outlet areas. In many cases, a local operator may not be informed of added load (new customers), resulting in the occurrence of serious overloading.

It was also indicated that soil and climatic conditions are suitable for lagoons, the cost is amenable to lower priced land, and that generally favorable conditions exist for continued lagoon use.

A trend present in other states, which will probably become a requirement soon, is the increase in the number of cells ". . . to provide more efficient treatment."

TENNESSEE - A recent visual inspection of single-celled facilities in Tennessee disclosed that the overall physical and aesthetic appearance of lagoons is good although there is considerable variation in maintenance. The reviewer concluded that in western Tennessee for communities with populations of less than 3000, the domestic wastewater lagoon is a satisfactory means of providing economical treatment. Most facilities examined averaged over 85 percent BOD removal for the year with highs of 95 percent and lows of around 75 percent. Effluents were typically of good quality, odor free, and except for algae cells, judged to be satisfactory.

There are currently no effluent standards for wastewater treatment plants. Eighty to ninety percent BOD removal is desired. Ponds are loaded to 30 to 40 lbs. BOD/acre/day (200 full-time people at .17PE) and appear to meet this requirement.

State officials believe that single-celled units have performed satisfactorily for the past fifteen years. Two-celled units are now required, which should further decrease the coliform counts although the total BOD will probably not be altered to any appreciable extent. Regular sampling is required and satisfactory compliance is achieved.

Chlorination is required when bacteria count is judged too high over considerable periods of elapsed time. At present, about 10 percent of the facilities are chlorinated.

In addition to low initial costs and relatively low operating costs, existing plants have not had to be bypassed nor have some of the operating problems of mechanical plants been encountered.

As previously stated, lagoons have been approved for the western third of the state where soil and topography are amenable and where most discharge into deep, dry sand ditches causes no immediate pollution by the time it reaches permanent stream flow. These waters are not generally used for public or stock water supplies and receive limited recreational use.

MISSISSIPPI - Mississippi officials appear to take a firm stand on lagoons. The state does not condone single-celled units and apparently realizes that multiple-celled facilities do not reduce the total BOD load as a result of algal cell generation.

State officials do not feel that aeration of existing lagoons is effective in solving their problems due to the heavy erosion.

Construction of conventional treatment plants is the current goal in the state. After this is achieved there are plans to initiate adequate records to insure correct operation of existing plants.

A major part of Mississippi's problem is the lack of certified operators, resulting in little control over performance and an essentially sporadic reporting system.

Odors from rotting algal mats, questionable coliform reductions, low or uncertain suspended solids reduction, and low BOD and COD reduction have led state officials to realize they do not know the effect lagoons have on receiving water quality. Lagoon effluents appear to cause further reduction in water quality. The Mississippi Air, Water and Pollution Control Authority is now proceeding cautiously and granting only limited approval of lagoons.

FLORIDA - Florida, by state statute and published standards, requires a minimum of 90 percent BOD5 removal prior to effluent disposal. None of the lagoons in this state receive raw wastewater directly. They are referred to as "polishing ponds" and appear to be equivalent to tertiary ponds.

Loading of these facilities varies with use. Thus ponds intended for use primarily as evaporation or percolation ponds are loaded at 10 to 12 lbs BOD/acre/day and the polishing or tertiary ponds are loaded up to 50 lbs/acre/day. Some form of approved secondary treatment other than lagoons precedes each of these facilities. Evaporative ponds are designed four (4) times as large as polishing ponds and have no discharge. Vegetation and shore growth is a problem. No data are available on effluent from Florida polishing ponds.

GEORGIA - Lagoons are considered adequate to meet the treatment needs of this state. They are in use, in small rural towns as interim facilities, or for polishing of plant effluents. Their low cost and maintenance factors are cited as a primary advantage.

The minimum system in Georgia is composed of two ponds in series, with a baffle across the first. Ninety day storage is required in the second cell. Year-round discharge is permitted with disinfection practiced depending on the existing quality of the receiving stream.

Although a concrete or other impervious apron is required to reduce emergent weed growth, many of the facilities were reported to suffer from periodic odors, algal and grease balls and heavy growth of duck weed.

OHIO BASIN

Information from Ohio Basin states demonstrate that a wide variety of factors can contribute to dissatisfaction with lagoons. If one includes Missouri and Illinois, a fairly uniform picture of non-acceptance of lagoons as a secondary treatment process extends into the New England states. Limited population and generally unsuitable terrain of much of West Virginia is equally unsuited to lagoon installations. Population pressures and high land costs work against extensive lagooning in Pennsylvania, Ohio and parts of Indiana.

The states in this region have abundant rain, a generally amenable climate, but considerable ice cover in winters. Performance studies are few but sufficient in scope to suggest that effluent quality can be quite poor at times, probably due primarily to climate. Rising land costs and population density make the creation of extensive lagoon areas impractical and costly.

Presently, supplemental aeration and oxidation ditching are being considered to augment existing facilities. It is doubtful whether many more facultative facilities will be constructed with the exception of isolated, rural communities.

OHIO - Ten State Standards are the accepted criteria for lagoon design in Ohio. Rising land costs and complaints from algal growth and odors have fostered a generally unfavorable attitude toward unaerated lagooning.

At present, no lagoons are permitted except for small isolated rural communities.

KENTUCKY - The Kentucky Water Pollution Control Commission is responsible for design approval. Low loading is specified at 100 P.E./acre/day or a maximum of 20 lbs/BOD/acre/day/ whichever is larger.

There is rather poor reporting by operators of the few lagoons within the state.

Terrain restricts lagoons in the western half of the state where the predominant attitude is that lagoons generally perform in a fashion suitable to protect the receiving streams in a "reasonable" condition. The meaning of this statement is not clear. The two biggest problems appear to be inadequate soil, with consequent leaking or seepage, and generally poor maintenance and repair of facilities.

INDIANA - Rising land costs presently make the prospects of additional lagoon construction questionable in Indiana.

With 90 percent BOD removal specified as adequate secondary treatment for municipal facilities, many existing plants are capable of achieving a 20 to 25 mg/l BOD in the effluent. Thus, treatment is considered adequate to meet the standards but many of the clear low flow, streams are not adequate to receive lagoon effluents. Although BOD, D.O. and water depth are specified for reporting, in practice only visual inspections are conducted on a monthly basis. Operating efficiencies as high as 90 to 92 percent are reported, but no regular sampling is conducted to identify any lower figures.

No effort is made to measure stream quality below lagoon outfalls but a 3:1 dilution is specified during discharge periods. Algal growth and pond leakage are specific problems encountered.

According to the Stream Pollution Control Board, most of the lagoons in the state are operating below the design load and few complaints are received or operating problems encountered. The State Board of Health reports one three-celled installation which receives a considerable portion of its wastes from a cheese processing plant; it is severely overloaded and generates objectional H_2S odors during much of its operation.

The Ten State Standards are used in the review of proposed designs which are mutually acted upon by the State Board of Health and the Stream Pollution Control Board.

WEST VIRGINIA - Most of the problems encountered in this state are due to faulty initial design and present operation, according to the Division of Water Resources.

No regular sampling is required and the responsibility to inspect and take remedial measures rests with individual municipalities.

Many older facilities, because of improper waste distribution design, have accumulated sludge deposits and generally faulty distribution within the cells. Apparently, improper or inadequate design loading (BOD) is at fault. Part of the problems resulting in septic conditions are blamed on inadequate depth control, especially during construction of the older lagoons. Poor community maintenance and lack of daily testing result in very poor operating data, although some facilities have reported 90 percent plus BOD removal during the summer.

GREAT LAKES REGION

With the exception of Illinois, these states have been generally satisfied with lagoon performance. Minnesota, Wisconsin, and Michigan, although satisfied with the concept of extended detention and periodic release of effluent to coincide with high river flow, are experimenting with other means of effluent disposal. Iowa apparently feels effluent quality does not significantly alter receiving water quality in local situations. There are no studies to verify this at present.

Illinois has taken the most positive stand; based on new recommendations, no lagoon effluent will be satisfactory as presently produced. Illinois does regard lagooning as equivalent to secondary treatment; however, they credit the first cell with only 75 percent removal. Thus, additional cell(s) are needed to provide a sufficiently high degree of treatment.

Forty-one percent of single-celled units did not achieve expected efficiency; sixty-four percent of two-celled systems failed and eighty-seven percent of three-celled facilities failed to achieve their design process efficiency. Part of the reason for these failures is that lagooning is being expected to perform operations it appears unable to do. Although typical fecal and other wastewater BOD are reduced to appropriate levels, the release of nutrients and subsequent algal growth create an effluent BOD unsuitable for discharge. This problem is discussed at length elsewhere in this report.

Porous soils in some of the northern state locations have created problems and many of the facilities are routinely sealed before operation.

WISCONSIN - Lagoons in Wisconsin are considered adequate to meet the treatment needs of the state. They are regarded as secondary treatment since the effluent BOD_5 is in the range of 20 to 30 mg/l. Many of the facilities are temporal, serving only during seasonal vacation peaks; effluent from many units dissipates before reaching surface waters. There is considerable subsurface seepage evident but possible effects on ground water supplies are unknown. Soil types present some problems related to ineffective sealing of bottoms.

Operating efficiencies in excess of 90 percent with very low BOD_5 are common during ice free periods. Ice cover from five to seventeen inches is common over much of the state during winter. After extended periods of such cover dissolved oxygen is depleted, resulting in insufficient photosynthesis; offensive odors commonly develop in January, February, and March.

Periodic grab samples are taken, often only once a year. District personnel conduct the sampling and evaluate the general condition of the facility. Problems found include those associated with earthen structures, such as rodents and ineffective seals. Algae growth is also regarded as a problem in some lagoons.

Some small municipalities have encountered problems when creamery or food processing plants are added to a line, causing overloading. Such facilities commonly do not achieve satisfactory treatment. But overloading is not always the reason for apparent failure to achieve satisfactory BOD reduction, nor does it explain why an apparently overloaded lagoon achieves high BOD_5 reduction and high quality effluent.

Like most states, Wisconsin suffers a lack of manpower to collect and analyze lagoon performance data. Only 26 of the more than 96 predominantly municipal lagoons identified in the state have reported data. Most of these date are insufficient to use in analytical comparison.

IOWA - Iowa appears to have a rather relaxed attitude about lagoons. They are recommended for use over small package plants for places with populations or population equivalents of less than 1,000.

Although winter discharge is not supposed to occur, it does. However, little concern is expressed about the situation.

The Ten State Standards with a lower loading of 20 lbs. BOD/acre/day are followed. It is stated that no short-circuiting occurs; however, it is probable that all lagoons suffer from some degree of short-circuiting.

Elaborate forms are provided to each treatment facility and operators must be certified. Records disclosed that more than 25 percent of the operators do not understand the directions for filling out the form. Some forms were obviously "dry-booked". Most of the operators, however, reported conducting the relatively simple Relative Stability Test. It is impossible to relate the data from these reports to other data gathered.

MICHIGAN - The assimilative capacity of receiving waters appears to be responsible for the attitude that lagoons are generally adequate in Michigan and several northern Great Lakes states. Thus, discharge is permitted in spring and fall during heavy stream flow and lower recreational use.

Complete testing of waters "must" be accomplished before discharging effluent. Sufficient retentive capacity is covered in design to accomodate water detentions, especially over ice cover periods. Measurements of COD, BOD, coliform, solids, D.o and pH are required.

Officials of this state are quite concerned over phosphate additions to the Great Lakes, although significant phosphate removal is not accomplished by lagooning.

The concept of land disposal of lagoon, as well as other treatment plant effluent is being examined in this state as a possible means of disposing of this water and recharging ground water supplies. Public acceptance of the idea still impedes progress in this area to some extent.

Specific directions offered by the State, if implemented by operators, would insure much more satisfactory operation.

MINNESOTA - The Minnesota Water Pollution Board considers lagoons the best form of secondary treatment for small installations. Discharges, usually limited to spring and fall highwater flow periods in the receiving streams are regarded as adequately diluted. In addition, discharges are scheduled when algae growth is not a major factor.

Each lagoon installation is responsible for a quarterly influent sampling and analysis report before and during discharge; examination of the records showed little information had been collected and there was not a great deal of concern about the sparcity of information. If data are not recorded, the offender is counseled and some efforts are made to obtain the data. The records, however, have no consistent pattern; numerical values reported are not low enough to consistently be called secondary treatment. While records do not show much concrete evidence of performance, the state feels effluent standards are being met.

ILLINOIS - The State of Illinois has established stringent effluent criteria and is doubtful whether lagoons, as presently designed, will be able to accomplish such a high degree of treatment (data presented in Appendix B show that unaerated facilities cannot). Revised 1971 state design criteria, as detailed in EPC Technical Policy 20-24, provide for different loading rates depending upon climate, i.e., 22 pounds for the northern part of the state, 26 pounds for central Illinois, and 30 pounds BOD/acre/day for the area south of East St. Louis, Illinois. BOD or suspended solids, including algae cells must also be removed to meet the intended treatment requirements and effluent criteria. This may be accomplished with mechanical settling tanks, chemical addition, precipitation or other means of removal.

These criteria are only technical policy; they are not standards enforceable by law. The proposed requirements keyed to stream flow availability, are detailed below:

Stream Dilution Availability	Effluent BOD	Effluent SS
2 to 1	20 mg/l	25 mg/l
1 to 1	10 mg/l	13 mg/l
Less than 1 to 1	4 mg/l	5 mg/l

In many streams lagoon effluent cannot meet the requirements.

Disinfection would be required during recreational months between April 1 and November 1 to accomplish a maximum of 2000 cells/100 ml for secondary waters and 400 cells/100 ml for primary contact waters. If, as the contractor believes, the Ten State Standards lagoon design criteria virtually insure short-circuiting, no lagoon in the Midwest can achieve these effluent objectives without disinfection. The present computerized method of recording data is being updated by the Federal EPA and will be made available to state engineers in six to nine months. Access is presently limited to drainage basin identification; the system will be revised to allow retrieval of data by town. The operating history of individual plants will be shown through sample measurements by state laboratories. Separate listings will show design flow, population equivalent and measured flow. Records presently do not show influent BOD or SS data. Plant operators are responsible for these data, but do not usually keep records. This lack of response will appear on the new system. Most lagoons also do not have flow measuring equipment, although all new treatment facilities in the state are being required to provide a method of measurement.

Illinois does not feel present technology can efficiently remove algae or that proper design will insure meeting BOD standards for lagoon effluent because of algae growth. As a result neither algae removal nor absolute compliance with BOD standards is required. Filtering of algae presently is not permitted in BOD samples since it removes suspended organic material, which should be included in the BOD test.

When the present system is completed, legal action designed to enforce these standards is planned. If plants improve facilities on schedule and approved modifications are considered correctly designed to meet the standards, no action will be taken by the state. However, if there is no cooperation by plant officials, a ban on new construction will be used to force compliance.

There is currently no analytical work done by the operators in Illinois. State teams sample three to ten times a year, but there is no flow measurement or determination of load on the stream. No measurements were found which could indicate the condition of the stream.

In the future state effluent standards will be the controlling factor and raw waste strength will not be as important since there will no longer be a percent reduction to achieve. In Illinois lagoons will be approved if they have at least three cells and are chlorinated or have algae removal as needed.

MISSOURI BASIN REGION

North and central plains states generally agree on the adequacy of lagoon facilities. Detention during ice cover periods, high evaporation and clear sunny days over much of the region produce relatively high quality effluent during most of the year. The agricultural nature and sparse population of the area make multiple cell lagooning an economical treatment method.

MISSOURI - Philosophically, Missouri should be excluded from this region during any discussion of performance. Contrary to the other Plains states, Missouri, which reported having the greatest number of lagoon facilities in the nation, finds lagoon performance generally not satisfactory.

As in many other states, standards acceptable ten or fifteen years ago are no longer adequate. While water pollution control authorities recognize this inadequacy and are not satisfied with lagoon performance, they are relatively powerless to ameliorate it at present.

Some of the poorest examples of water quality preservation can be seen around the metropolitan St. Louis area, where smaller communities and installations such as trailer parks, schools, and motels create problems of fantastic proportions. In one county, there are over 270 such facilities. They are poorly operated and monitored, and the small receiving streams are totally unable to cope with their effluents.

Effective enforcement of health and lagoon treatment and performance recommendations is difficult in much of Missouri. There are few sanitary codes to implement these recommendations; the only effective enforcement lies in civil suit under public nuisance doctrine.

SOUTH DAKOTA - The State of South Dakota accepts and encourages the use of lagoons for smaller communities. Larger communities must provide the equivalent of tertiary treatment to remove algae and nutrients.

Every attempt is made to design new facilities so that effluent will meet state standards. Package plants followed by holding or stabilization ponds are common and encouraged. Most are designed to retain effluent during recreational season for later discharge. A high degree of versatility is possible and a high degree of stability achieved.

This state is unique in that it has the highest percentage of communities represented of all states in the STORET data. Officials regard this kind of information retrieval as a valuable asset in any water quality monitoring program. Information is updated with average yearly performance figures. This data shows that most community facilities average 90 percent BOD_5 reduction during the year. There is some question as to the validity of the STORET data which shows an almost identical match between influent and effluent BOD_5 data, i.e., 272/28, 238/20, 306/31, 306/31, 272/27, 279/28, 245/24, 204/20. It may be fortuitous that lagoon facilities scattered throughout the state operating under diverse circumstances can produce such consistent treatment results.

NORTH DAKOTA - Multiple-celled systems and high rates of evaporation result in few documented effluent problems. No winter discharge is practical and few bacteria are released after second cell treatment. Phosphate and nitrate levels are monitored prior to spring discharge and volumes are adjusted to stream flow where applicable.

A generally high degree of satisfaction is recorded. Additional construction of lagoons is anticipated.

WYOMING - Overloading of existing facilities is viewed as a major problem in Wyoming as the urban population increases. Originally designed as single units, recommended facilities are now two or more cells in series; aerated facilities are suggested followed by oxidation ponds.

Initial low costs and minimal maintenance make this form of treatment very suitable. Performance is judged very good if properly designed; the basis for this judgment is periodic BOD examination. No regular testing procedures are in effect, however. Organic loading of 17 lb/BOD/acre/day is specified in design, and efficiencies are reported as high as 95 percent during the summer and 75 percent in the winter. Operators possess minimal qualifications, if any, and no certification law is in effect.

Continuous monitoring of state streams is conducted by the fisheries staff and unsatisfactory conditions are reported rapidly. As one official said, "All streams are supporting good trout populations so the effluent can't be too bad."

MONTANA - Montana requires only annual reporting on their more than 125 lagoons. The State Water Pollution Control Council does not presently have the staff to implement more stringent record keeping. Lagoons generally achieve 85 percent BOD removal, with more than 85 percent removal during summer. Total detention is practiced during the winter, especially if algae are a problem. Insufficient operating data are available to verify the above or to determine when problem conditions exist.

A major problem is those lagoons with a high rate of flow in proportion to the number of people served. This occurs in many areas with a high groundwater table where summer irrigation is practiced in adjacent areas. Four cells in series are recommended with a total surface area of 100 PE/acre/day.

The state is generally pleased with lagoons, and maintains that it has more problems with improperly operated mechanical plants.

NEBRASKA - Based on location, Nebraska should encounter few problems with lagoon operation. More than two hundred municipal facilities are identified in the state. Lagoons are considered the most economical for small communities. No samples are required and none have been recorded for this state. On the basis of samples which have been analyzed by the State Department of Health, routine reduction of BOD_5 by 85 percent on filtered samples has been reported.

The failure to conduct normal huusekeeping activities such as weed cutting, insect spraying and bank deterioration was cited as a problem. Other negative success factors included faulty design and overloading.

MID-ATLANTIC REGION

The realization by state officials that lagoon effluents "may not" be adequate to protect receiving waters is a tacit admission of developing problems. Increased awareness of the possible effects on estuarine waters has helped augment this general realization. Increased population and rising land costs will mitigate against further construction in most states.

Chlorination is widely recommended and most states realize the need to upgrade existing lagoon facilities. Additional work is required, however, to adapt chlorination technology to lagoon effluent treatment.

VIRGINIA - No regular sampling of lagoons is conducted in Virginia and visual inspections are reported on an infrequent basis.

Lagoons are granted a limited tolerance but their future use will probably be discouraged. The Water Control Board does not feel lagoons meet receiving stream standards in winter. Total detention of up to 90 days is practiced near heavily used recreational areas in summer.

Most facilities are small and loaded to 200 P.E./acre/day. BOD removal of 85 percent is required by the state but spot checking disclosed that most facilities average 80 percent removal or less. All facilities provide for chlorination; although detention may be specified for some facilities, all have the potential of discharging all year long.

Rapid development has resulted in overloading of many facilities. Septic odors are occasionally reported.

MARYLAND - Removal of 80 to 85 percent BOD_5 is sufficient to classify lagoons as adequate secondary treatment in Maryland. The only problems encountered have been in badly overloaded facilities. Sampling is recommended four times per year but personnel shortages have prevented this. The State Department of Health is satisfied with performance and will probably authorize additional construction, although cost factors will undoubtedly become more of a consideration as urban land costs rise.

Soil conditions have created problems with pond bottom sealing. Concern has not been expressed over the possibility of pond water contamination but rather over the fact that sealing to prevent leakage has increased the basic cost of the facility. Cost has been the main consideration to date.

It is felt that aeration improves existing facilities. Implementation of aeration will probably be offered to correct problems as they develop. A mandatory certification law has been passed but at present operators are rather poorly qualified.

NORTH CAROLINA - North Carolina gives approval to lagoons at the present time. Multiple systems have also been recommended.

Approval of lagoon design does not reflect a choice over conventional plants nor does it reflect a growing awareness by state officials of design failures. Officials felt that many problems could be met by proper maintenance and operational control rather than by new standards or criteria.

Examination of STORET data revealed that, although some lagoons are reported to achieve 80 to 90 percent BOD removal, most do not. A figure of less than 75 percent is more realistic.

It would appear that state officials need valid data before lagoon performance can be documented.

SOUTH CAROLINA - The Pollution Control Authority considers lagoons adequate secondary treatment because "they provide 80 to 90 percent BOD removal".

State effluent requirements for coliform bacteria are sufficiently high that chlorination is strongly recommended for all new operations. There is no law, however, to require disinfection in older facilities.

The Pollution Control Authority has suggested additional (mechanical) aeration. Originally, this supplementary oxygen source was intended only for troublesome periods, but many installations run them continuously. The aeration can keep organic solids suspended causing heavier loading than originally designed. More facilities are being built with aerated lagoons, as this modification has gained in acceptance and as land prices have increased.

Visual inspections are conducted three times a year with chemical and biological examinations made much less frequently due to manpower restraints. Under the present surveillance system it is questionable whether the state really knows anything meaningful about lagoon performance.

Although a mandatory certification law went into effect last year, many older operators certified under a "grandfather clause" will not be affected.

Odors and algae are regarded as primary problems, especially in public relations.

NORTHEAST REGION

Lagoons are generally unsatisfactory in this region. Heavy ice and snow cover for extended winter periods necessitate total retention. The total number of lagoons in this entire region is less than one typical midwestern urban/suburban county--undoubtedly the result of poor success, high population density, unfavorable climate, and high land values.

It is doubtful, in light of today's interest in water quality preservation, that any additional lagoons will be constructed in this region except, perhaps, in isolated seasonal camps or other recreational areas.

NEW JERSEY - New Jersey has very limited experience with non-aerated lagoons due to the high degree of urbanization, space limitations and soaring land costs. It is unlikely that lagoons will be utilized to any extent in this state.

NEW YORK - Generally poor success is encountered here. The Ten State Standards are the general design guide. Low loading at 100 PE/acre/day yields an average of 60 percent BOD reduction or less.

MASSACHUSETTS - Municipal lagoons have not been approved for construction in recent years.

The Division of Water Pollution Control is relatively new, formed in 1967, and as a result has not sampled the existing facilities. No operational data is available.

Excessive land costs and professional opinions that lagoons do not provide adequate secondary treatment dictate against further construction in this state. Concern for safety and ill-defined operational problems are expressed as additional reasons for their disuse.

NORTHWEST REGION

In this area, lagoons are generally considered adequate treatment. Extended periods of cloud cover in portions of Washington and Oregon reduce the efficiency of lagooning but this is not regarded as a serious problem since sufficient storage is provided in most designs.

IDAHO - Idaho is quite pragmatic about lagoons and is attempting to solve existing problems through operational adjustments. Considerable differences in elevation produce problems in operational temperatures. Many sport camps and other season operations are designed for total containment at all times or during periods of low stream flow.

Lagoons are regarded as secondary treatment although some do not achieve 85 percent BOD reduction due to secondary algal growth. As a result, facilities are designed with increased detention time.

Lagoons are considered a desirable compromise here because of economic considerations. No mandatory operator requirement is presently in force. Sampling of non-aerated facilities is accomplished by grab samples two to three times annually.

If state bacteriological standards are not met, effluent is chlorinated. Average coliform counts may not exceed 1000/100 ml (MPN) with 20 percent of the samples not exceeding 2400/100 ml.

As with states seeking to preserve high water quality, dissolved oxygen must not be less than 75 percent of saturation at seasonal low or less than 100 percent saturation in spawning areas during spawning, washing and fry stages of salmonoid fishes.

In line with these standards total detainment is specified for many facilities.

WASHINGTON - Potential effluent is contained either in the primary facility or in subsequent holding cells so that few facilities discharge to receiving streams. Where effluent is produced, it is often chlorinated, and in many cases sand filters are employed to remove algal cells.

Some facilities have highly seasonal applications in which total flow is contained.

Isolated routine measurements are utilized to determine efficiency and help municipalities overcome operating difficulties.

Where the effluent is not determined a detriment to receiving waters, treatment is considered adequate.

Some installations have augmented normal operations during periods of peak loading (cannery and vegetable processing) by the addition of supplemental air supplies. These are removed from service after peak loading.

OREGON - Varied climatic zones in Oregon, as in other coastal states, create varied patterns of efficiency. Sunny locations produce acceptable effluent quality while areas of extended cloud cover produce less satisfactory products. Total containment is practiced at higher elevations which are essentially season operations. Mechanical aeration is also practiced, followed by a two or more celled system or "polishing ponds". Although subsequent retention and oxidation further reduced the BOD and SS, the quality is not exceptional and timed release of effluent is practiced.

Algae and floating plants become periodic problems. Chlorination is practiced in many installations.

Research at Oregon State suggests that use of effluent water for irrigation purposes might be a more satisfactory means of disposal than the use of streams.